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Jamie Diatta
DePaul University, jamediatta@yahoo.com

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LEAPFROGGING OR GREEN WASHING?

An Economic, Social, and Environmental Impact Analysis
of Rural Solar Electrification Programs in the Fatick Region of Senegal

A Thesis

Presented in

Partial Fulfillment of the

Requirements for the Degree of

Master of Science

June 2010

BY

Jamie Diatta

School of Public Service
College of Liberal Arts and Sciences
DePaul University
Chicago, Illinois

DEPAUL UNIVERSITY
College of Liberal Arts and Science
School of Public Service

This thesis was presented

by

Jamie Diatta

It was approved by:

Thesis Director: Dr. Marco Tavanti, Associate Professor, School of Public Service

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Jamie Diatta, M.S.

DePaul University, 2010

ABSTRACT

Rural solar electrification programs are accelerating the pace of international development by delivering electricity to some of the world's most remote communities. Electricity is widely-perceived as a harbinger of economic, environmental and social change. Through the Clean Development Mechanism (CDM) of the Kyoto Protocol, companies and countries qualify for Carbon Credits by transferring green technology, such as solar electricity, to developing countries. The CDM has created an international framework for technology leapfrogging. The Fatick region of Senegal, in West Africa, is a case study in technology leapfrogging. In this coastal farming region, slim, sleek solar panels decorate the grass roofs of traditional African mud huts. While the West is touting rural solar electrification as a win-win solution to international development and climate change, many rural Senegalese are less enthusiastic about their new-found electricity. Prompted by legitimate concerns voiced by rural Senegalese, this study attempts to measure the economic, environmental, and social impacts of rural solar electrification on Fatick residents. Qualitative data was gathered from eighty-one in-depth, in-person interviews in ten rural communities in the Fatick region. The results indicate that Fatick residents are gaining no measurable direct or indirect economic benefits from solar electricity. In examining social impacts, the results indicate that solar electricity has brought no improvements in women's empowerment. The results do indicate, however, that solar electricity has brought marginal improvements to the environment, education and community health. The data establishes that rural solar electrification programs in their current form fail to deliver promised advancements to developing countries. Interestingly, manufactures of solar equipment and those transferring solar technology under the CDM are accruing benefits from rural solar electrification. This leaves one wondering if rural solar electrification programs would be better described by the term green washing rather than leapfrogging. The thesis concludes with fourteen recommendations for improving the impact of rural solar electrification programs on residents in developing countries.

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ABBREVIATIONS

ASER	Senegalese Agency for Rural Electrification
CDM	Clean Development Mechanism
CERER	The Center for Renewable Energy Research and Study
CFA	Communauté Financière Africaine
CRSE	The Energy Sector Regulatory Commission
CSR	Corporate Social Responsibility
DC	Direct Current
GNI	Gross National Income
HDI	Human Development Index
IAP	Indoor Air Pollutant
JICA	Japan's International Cooperation Agency
kWh	Kilowatt-hour
LEA	The Applied Energy Laboratory
MDGs	Millennium Development Goals
PSAES	Senegalese German Solar Energy Project
PV	Photovoltaic
tC	Tons of Carbon
UN	United Nations
UNEP	United Nations Environmental Program
USD	U.S. Dollar
Wp	Watt Peak

CHAPTER ONE INTRODUCTION

1.1 The Role of Electricity in International Development









Electricity is an important, yet often overlooked, component of international development. In places where doctors and schools are sparse, electricity may seem more of a luxury than a priority. Yet, in many of the rural corners of the world, access to electricity establishes a foundation for development; it has the power to propel development initiatives forward. For example, electricity allows rural health clinics to cool and store vaccines and medications. It gives children adequate lightening for doing homework in the evenings. It reduces the amount of time women spend on household chores, thus affording them free time to pursue other activities, such as evening literacy classes or income generating projects. While electricity may not be a prerequisite for development, it frequently serves as a catalyst in the development process. In a recent report titled *The Energy Challenge for Achieving the Millennium Development Goals*, UN-Energy (2005) states:

Currently, 1.6 billion people do not have access to electricity. This situation entrenches poverty, constrains the delivery of social services, limits opportunities for women, and erodes environmental sustainability at the local, national, and global levels. Much greater access to energy services is essential to address this situation and to support the achievement of the Millennium Development Goals (UN-Energy 2005, 2).

The Millennium Development Goals (MDGs) are eight international development goals brought forth by the United Nations (UN). All UN member states and numerous international organizations have agreed to work towards these goals, which are sub-

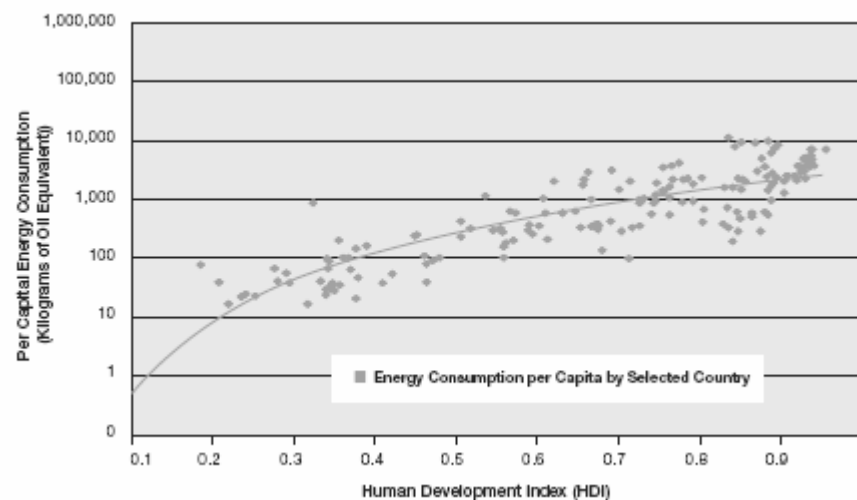
divided into twenty-one specific targets. Access to electricity is not one of the eight primary goals, nor is it one of the twenty-one targets. However, numerous experts agree that access to electricity is directly linked to the MDGs (Venema and Cisse 2004; Sarr and Thomas 2005). Table one lists each of the MDGs and offers examples of how energy and electricity can affect each individual MDG.

Table 1. Electricity and the Millennium Development Goals

Millennium Development Goal	Effect of Electricity on MDG Achievement
 1 Eradicate Extreme Poverty and Hunger	Electricity can be used to develop micro-enterprises and production activities, which ultimately creates employment and income.
 2 Achieve Universal Primary Education	Electricity enables students to study after dark, allows schools to go on-line with computers, and draws high-quality teachers to rural areas.
 3 Promote Gender Equality and Empower Women	Electricity has the potential to reduce the time women spend on chores, freeing up time for evening literacy classes and income-generating work.
 4 Reduce Child Mortality	Electricity enables families to cook with modern technology, rather than over open fires, which pose safety and health risks to women and children.
 5 Improve Maternal Health	Electricity permits women to delivery babies by light bulb rather than candlelight. It reduces exposure to Indoor Air Pollutants, which negatively affect fetal and maternal health.
 6 Combat HIV/AIDS, Malaria and Other Diseases	Electricity improves the ability of health clinics to store medications. Public health messages are frequently disseminated through electrical equipment such as TVs and radios.
 7 Ensure Environmental Sustainability	Solar electricity offsets the need for fossil fuel generated electricity.
 8 Develop a Global Partnership for Development	Electrification projects create partnerships between developing countries and developed countries. This is enhanced by the Clean Development Mechanism of the Kyoto Protocol.

The correlation between electricity and development is clearly illustrated in Figure One, which depicts the relationship between the Human Development Index (HDI) and electrical consumption. The HDI is a measurement tool created by the United Nations Development Program that ranks the level of development in one hundred and eighty-two countries. It compares factors such as life expectancy, education levels, and standard of living (Klugman 2009, 11). A higher HDI level reflects a longer-living, better-educated society with a high standard of living. Figure One indicates that countries that consume more electricity have a higher HDI level, and are therefore more developed than countries that consume less electricity. While it may be difficult to determine if electrical consumption precedes development or visa versa, it is difficult to dispute that there is a strong, direct positive association between electricity and development.

Figure 1. HDI and Electrical Consumption



(UN-Energy 2005)

Regionally, African countries have the lowest rankings in the Human Development Index and they consume the least amount of energy worldwide. More than sixty per cent of

Africans lack access to electricity (Wamukonya 2007, 6). “With nearly one billion people, Africa accounts for over a sixth of the world's population, but generates only four per cent of global electricity” (The Economist 2007). The need for energy infrastructure in Africa appears great. West Africa in particular, which is the subject of this study, consumes less electricity than other part of Africa and any other part of the world (Sarr and Thomas 2005, 8).

With a clear need for electrical development in Africa, the public, private and non-profit sectors have partnered together to create innovative methods for delivering electricity in Africa and thus facilitating international development.

1.2 Decentralized Rural Electricity

Across Africa, large and medium-sized cities have long benefited from centralized electricity. In areas with a high concentration of people, it is profitable for electric companies to deliver electricity, even when that electricity must be transported from its centralized production center. As of 2007, approximately thirty-nine per cent of Africans lived in urban centers (Zlotnik 2008).

In rural Africa, populations are often dispersed into small towns and even smaller villages. In these areas, some of which are remote, it is typically unprofitable to transport electricity long distances for relatively few consumers. Thus, much of rural Africa has never been electrified.

Without access to traditional electricity, rural Africans have found alternative ways to meet their electrical needs. Disposable batteries are often used to power flashlights and portable radios. Car batteries can be used to temporarily power small televisions or string up light bulbs for public events. Cooking is typically done over a wood-burning fire. Laundry is hand-washed and line dried, rather than run through a washing machine and dryer. Drinking water is cooled and stored in porous clay pots rather than refrigerators. People use homemade, reed-woven hand-held fans to cool themselves in lieu of electric fans or air-conditioners. Kerosene-burning lanterns or candles can provide dim lighting at night. Grinding and de-husking of agricultural products is done by mortar and pestle rather than electrical grinding machines. While rural Africans appear well-adapted to life without electricity, one might reasonably conclude that their life style is significantly more labor-intensive. The traditional biomass fuels used in rural Africa, such as dung and wood require significant time and labor to collect (UN Energy 2005). When finances are tight, people often go without even the most basics, such as fuel for lanterns.

Fortunately, centralized grid electricity is no longer the only option for electricity in rural African communities. Thanks to advances in technology, decentralized electricity is increasingly becoming a reality. Decentralized electricity is produced locally, rather than transmitted great distances from a central power station. It can be generated through an isolated electrical system, which supplies electricity to one or two homes, or by a minigrid system, which can serve entire communities, and sometimes even multiple small communities that are relatively close to each other. Isolated systems and minigrid systems can generate electricity through a variety of sources: solar power, wind power,

diesel fuel, hydro-generators, biomass, or hybrid systems (Reiche, Covarrubias and Martinot 2000, 52).

The most common forms of decentralized electricity are: solar home systems, solar-diesel hybrid generators, solar minigrids, and solar-diesel hybrid minigrids. A solar home system consists of photovoltaic panels, a battery, a charge controller, wiring and direct current (DC) outlets. Most solar home systems generate enough electricity to power a few low-demand appliances, such as a small TV, radio, lights and a fan. Solar home systems are available in various sizes, and can provide 10-100Wp. To give an example of how much electricity this is, “a 35 Wp solar home system provides enough power for four hours of lighting from four 7W lamps each evening, as well as several hours of television” (Ibid., 53). A solar home system has a high up-front cost for the installation of the equipment, but after the high up-front cost, there are no additional costs to generating electricity other than replacing the battery every few years. Solar home systems are widely used in rural areas in developing countries; more than 500,000 solar home systems are currently in use worldwide (Ibid.).

A diesel-solar hybrid generator is similar to a solar home system, but can often generate more electricity because of the addition of diesel fuel. A diesel-solar hybrid generator has similar upfront costs, but also has the added expense of diesel fuel, which is consumed as electricity is generated.

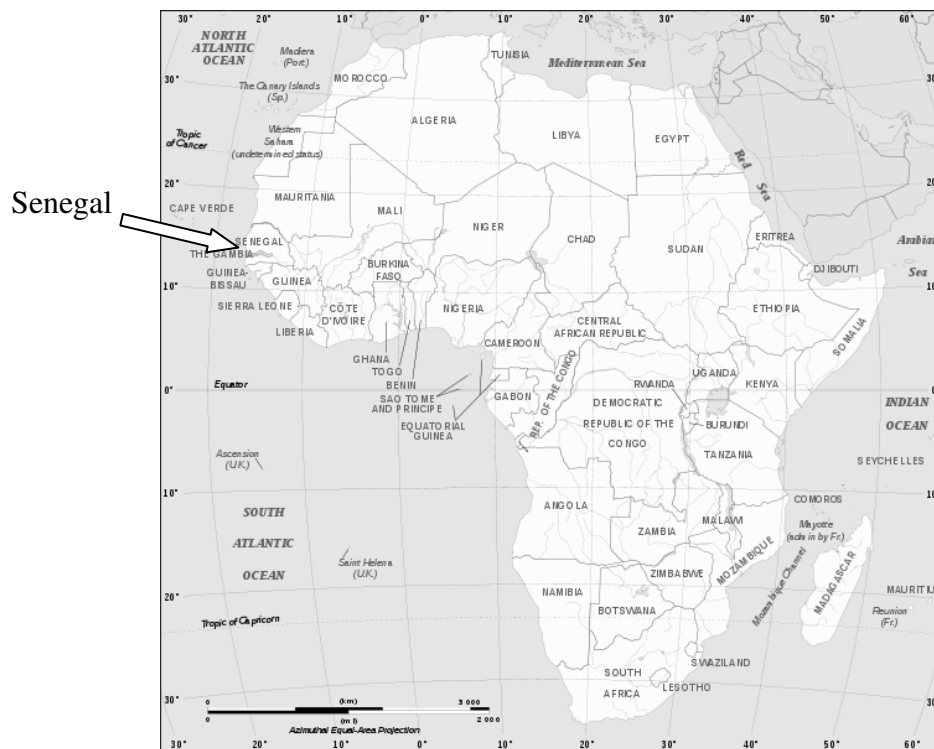
A minigrid system, whether all solar or hybrid solar-diesel, has the capacity to distribute generated electricity for entire communities. Similar to isolated systems, there is a limit on how much generated electricity minigrids can distribute. Thus, communities must coordinate how much electricity each household can use and when the electricity is used. This has proved a difficult task in many communities. Experiments are being done with electrical meters, which once installed can be used to measure and subsequently charge households which consume more than their pre-determined share of electricity (Ibid., 53-54).

Uses of decentralized electricity can be divided into three categories: domestic uses, productive uses, and public uses (Ibid., 52). Domestic uses include lighting, fans, refrigeration, radios, and televisions. Examples of productive uses include agricultural activities, such as fencing and irrigation; water pumping at wells; grinding mills; and sewing machines. Electricity can be used publicly at health clinics, schools, community centers, religious centers, police stations, and for street lamps and other safety-related uses.

1.3 Solar Electricity in Senegal

Senegal is a developing country in western Africa with fourteen million residents (Central Intelligence Agency 2009). Over half of the Senegalese population (58%) lives in rural areas (Ibid.). Traditionally, electricity has been available in Senegal only in urban areas.

Figure 2. Map of Africa



source: Wikipedia

Senegal receives an estimated three thousand hours of sunshine per year, and therefore is an ideal location for developing solar energy (ESI-Africa 2008). Recognizing this potential, the government of Senegal launched its first solar program in 1973, motivated in large part by the world oil crisis (Faye 2006). As early as the 1980's, the international community showed an interest in partnering with the Government of Senegal on solar projects.

One of the earliest international solar partnerships was the Senegalese German Solar Energy Project (PSAES). This project, which began in the 1980's, included the testing of new solar technologies, public education programs to familiarize Senegalese

communities with solar energy, and commercial distribution of solar equipment. By 1988, PSAES had installed: over three thousand solar home systems; two solar power mini-grid stations; four solar power mini-grid stations for health centers and tourist camps; and six solar water pumping stations. The PSAES project also trained over thirty local Senegalese as solar technicians. During the commercial distribution stage, PSAES experimented with a stratified pricing system, charging different prices to lower income families, middle-income families, and higher income families (Kanoute 2000).

In the late 1990's, Japan's International Cooperation Agency (JICA) invested more than US\$800,000 in solar technology in Senegal. On Senegal's Mar Island, JICA provided upfront financing for solar home systems to ninety-five island homes. Residents contributed 45,000 CFA (US\$88) upfront and then paid a monthly subscription fee of 3700 CFA (US\$7). As of 2002, JICA was experiencing a ninety per cent fee recovery rate and several additional island families had requested solar home systems. In addition, JICA installed other solar equipment on neighboring Senegalese islands, including: three solar power stations servicing five islands; ten solar powered desalination units; six solar powered water pumps; twenty-eight solar powered freezers; one hundred thirty solar home systems; and eight battery charging units (Ibid.).

The following chart outlines several other internationally supported solar projects in Senegal. This is not an exhaustive list of all projects and accomplishments, but rather offers a snap shot of how involved the international community has been in Senegal's development of solar energy.

Table 2. Samples of Recent Solar Energy Projects in Senegal

Partner Country	Partner Organization	Accomplishments
Spain	ISOPHOTON/ FAD	<ul style="list-style-type: none"> • 10,000 solar home systems (in progress) • 5 Desalination systems • 5 solar power stations • 662 community solar systems • Households initially contribute 20,000 CFA and then pay monthly subscription of 6,000 CFA • Partial funding provided by Spain's Fondo de Ayuda al Desarrollo (Development Assistance Fund) <p>(Sarr and Thomas 2005, 21; Gonzalez et al 2005)</p>
Spain	ASTERA	<ul style="list-style-type: none"> • 2,648 solar powered street lights • Solar Hybrid aero generator • Solar power stations • Solar water pumping stations • Desalination Systems • Battery recharges • Solar power provided to research centers, health centers, tourist facilities, cold storage, and schools • Telecommunications <p>(Sarr and Thomas 2005, 20-22)</p>
Italy	Aqua Per Gli Villagi	<ul style="list-style-type: none"> • Experimented with 3 types of renewable water pumping systems for irrigation • Budget of US\$86,500,000 <p>(Kanoute 2000)</p>
Belgium	Senegal-Belgium Project	<ul style="list-style-type: none"> • 7 solar water pumps for irrigation • 8 sanitary centers • 15 solar sea product drying systems • Budget of US\$226,000 <p>(Kanoute 2000)</p>
France	Alcatel-Lucent	<ul style="list-style-type: none"> • Solar GSM site on Bettenty Island, thus enabling island residents to use cell phones and other wireless technologies <p>(Alcatel-Lucent 2008)</p>
India	Senegal-India Project	<ul style="list-style-type: none"> • 267 solar home systems in Soune, Senegal • Solar system in 1 maternity clinic • Solar system in 1 sanitary center • Solar systems in 4 mosques <p>(Kanoute 2000)</p>

More importantly, perhaps, than the international investments that have supported Senegal's expanding solar power base are the changes that have occurred in Senegal's private, non-profit and public sectors. For a developing country, Senegal's private sector has shown a keen interest in renewables. As of 2005, Senegal was home to fourteen private renewable energy businesses. With the exception of solar panels and light bulbs, all components of Senegal's solar systems are now manufactured in Senegal. This includes, but is not limited to: batteries, cables, invertors, chargers, switches, breakers, fuses, battery capacity meters, and battery temperature sensors (Venema and Cisse 2004, 90; African Energy, n.d.)

In comparison to other West African countries, Senegal has a well-developed civic sector. This is often attributed to Senegal's long history of democracy and stable political climate. Some of Senegal's non-profit organizations serve as strong advocates for solar projects. One such association is the Federation of Organizations for the Promotion of Renewable Energy. This group has formed a network of solar maintenance technicians located in rural areas (Sarr and Thomas 2005, 33). "The most effective institutions involved in the promotion of photovoltaics are often rural associations which, beyond their participation in rural solar energy projects, also play a central role in the activities of their community" (African Rural Enterprise Development n.d., 3).

Like the Senegalese private and civic sectors, the Government of Senegal is also eager to expand electricity to rural areas of the country. In 1998, the Senegalese government declared that rural electrification was a national priority. To lead this initiative, the

government created the Senegalese Agency for Rural Electrification (ASER). ASER serves as the primary government agency charged with establishing electricity in rural Senegal. Shortly after creating ASER, the Government of Senegal also created several other regulatory and research bodies to support the growth of renewable energy in Senegal. Namely:

- The Energy Sector Regulatory Commission (CRSE)
- The Center for Renewable Energy Research and Study (CERER)
- The Applied Energy Laboratory (LEA)
- The Renewable Energy Semi-Conductor Laboratory at the University Cheikh Anta Diop

In 2002 the President of Senegal appointed Professor Christian Diatta (no relation to author) to the newly created position of Minister of Biofuels, Renewable Energy, and Scientific Research. The Government of Senegal has established a goal of thirty per cent rural electrification by 2015 and sixty-two per cent rural electrification by 2022. The government intends to reach these goals primarily through the development of decentralized rural electrification (Oxford Business Group 2008).

In September 2008 the Government of Senegal hosted Africa's first carbon forum. The goal of this forum was to match businesses interested in funding renewable energy projects in exchange for carbon credits with projects seeking financial assistance. The Clean Development Mechanism of the Kyoto Protocol allows for businesses and countries to gain carbon credits in exchange for funding clean energy projects. Through Senegal's carbon forum, twenty-five renewable energy projects were able to secure funding (Integrated Regional Information Networks 2008). In a September 2008

agreement signed by the Government of Senegal and the World Bank, Senegal will sell 120,000 tons of carbon credits in correlation with the Clean Development Mechanism (Gordon, Ndiaye and Bissett 2008).

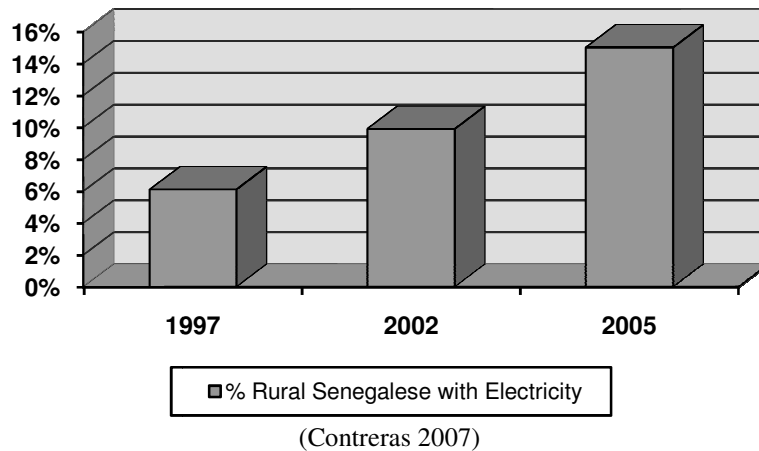
As an independent government agency, ASER has established its own goals for rural electrification, as depicted in table three (Venema and Cisse, eds. 2004, 81):

Table 3. Rural Electrification Goals of ASER

Timeframe	Newly Electrified Villages	Cumulative	Newly Electrified Homes	Cumulative	Rural Electrification Rate
2003-2007	3026	3026	163,288	163,288	51%
2008-2012	1922	4948	61,293	224,581	64%
2013-2017	1609	6558	60,680	285,261	74%
2018-2022	1327	7884	60,402	345,663	79%

Due to the active involvement of international partners, and the private, civic and public sectors, Senegal has made great progress with rural electrification. Of Senegal's 24,000 rural villages, only 286 of them had electricity in 1998 (Ibid., 79). From 1998 to 2002 an additional 650 villages gained electricity, primarily through the solar projects described above. By 2003, twelve per cent of rural Senegal had electricity (Contreras 2007, 1). Clearly, progress is being made.

Figure 3. Access to Electricity in Rural Senegal



In a 2006 interview with Germany's *Der Spiegel* magazine, Senegal's President Abdoulaye Wade said: "Right now, we (Senegal) have 1,400 solar powered television sets...We have 24,000 villages in Senegal, and they could all use solar power. My aim is to use solar power for heating, for schools, for public buildings. This I will do because it is in our interests. We don't have oil, which is why I helped set up an organization of non-oil producing countries, with the aim of developing alternative energy sources and solar power" (Der Spiegel 2006). Given the established connection between access to electricity and development, Senegal's commitment to electrification has the potential to greatly reduce poverty and help Senegal achieve the Millennium Development Goals.

1.4 Assessing Senegal's Current Rural Solar Electrification Programs

Clearly, Senegal and the international community have invested a great amount of time and money into developing decentralized rural electricity in Senegal. It seems that the future of rural Senegal is bright. Yet on a recent visit to Senegal, I found surprising contradictions to this promising future. I observed that several households equipped with

solar home systems were not using the equipment. Mostly, I met residents who were frustrated with the solar systems. Some residents complained about broken systems and a lack of available technicians to do repairs. Others complained that the monthly subscription rates were not properly explained to them and that once the solar systems were installed, they could no longer afford them.

I recall standing in one man's courtyard in 2006, squinting up at the contrast of high-tech solar panels perched on a pole alongside a grass-roofed mud hut. This man had stopped paying his monthly subscription fees long before my visit. The Senegalese government had disabled his solar home system to prevent him from using electricity, but had left the equipment in place. A proverbial flip-of-the-switch would allow this man electricity at no additional cost to the government. That electricity might allow him to work longer hours each day, thus earning more income. It would afford his children the means to do homework after dark. It would allow his wife to deliver their next child by light bulb, rather than candlelight. But no switch was flipped. To this day, solar panels rest unproductively alongside his grass roof, exposed to all of the humidity, rain and sunlight of a tropical African country.

It is possible that my 2006 observations were anomalies. But more likely, they are small indications that the future of Senegal's ambitious rural solar electrification program is not as bright as some would like to believe. While Senegal has come far with its rural electrification in the past decade, there is little research on what happens in communities after they receive electricity. It is widely assumed that electricity facilitates development

and improves standards of living, but in Senegal there have been no attempts to measure the impact of rural electrification.

Clearly, there is a need for an impact assessment of rural electrification programs in Senegal. This thesis is an initial attempt at an impact assessment. Due to limited time and funding, it is small in scope. In the following chapter, a literature review offers insight to published research in the field of rural solar electrification. Chapter Three, Methodologies, clarifies the research process used for this thesis. Chapter Four, the most extensive chapter, presents and analyzes the data, drawing conclusions when possible. Chapter Four also addresses the limitations and delimitations of this study. The final chapter, Chapter Five, provides recommendations for improving rural solar electrification in Senegal. These recommendations are geared towards: the Government of Senegal, the international public sector, the private sector, and Senegal's civil sector. Although small in scope, this thesis is written with the hope of motivating a larger, comprehensive impact assessment of Senegal's rural solar electrification programs. In addition, the goal of this thesis is to draw attention to potential performance gaps in rural solar electrification programs worldwide, with an eye towards improving their ability to address the MDG's and prompt international development.

CHAPTER TWO LITERATURE REVIEW

A review of current literature on rural solar electrification produces mixed results. Section 2.1 presents promising indicators that decentralized solar electricity is the future for the developing world, allowing countries to leapfrog over industrialization. Much of the literature in this section speaks of increasing global demand for solar technology paired with decreasing costs. Sections 2.2 through 2.4 present literature relating specifically to the economic, environmental, and social impacts of rural solar electrification, respectively. The scarcity of literature referenced in these three sections is a direct reflection of the lack of published research on the impacts of rural solar electrification. Section 2.5 highlights a few recurring concerns from the literature, including concerns about a lack of monitoring and evaluation, a lack of cost-effectiveness, and the implication that rural solar electrification programs may be doing more green washing than leapfrogging.

2.1 The Future Potential of Solar Electricity in Africa

Increasing demand and decreasing costs paints a promising picture for the future of rural solar electricity in Africa. In a study titled *The Role of Renewable Energy in the Development of Productive Activities in Rural West Africa: the Case of Senegal*, authors Sarr and Thomas (2005) describe how three decades of renewable energy experiments have established the availability of mature renewable technologies. This study also indicates that the cost of renewables has been declining for the past twenty-five years (Sarr & Thomas 2005, 10).

In a second study titled *Energy for Development: Solar Home Systems in Africa and Global Carbon Emissions*, authors Duke and Kammen (2005) state that “photovoltaic real module prices have fallen by a factor of sixteen since 1975.”

Authors Asi, Muneer and Khan (2008) contribute the decreasing cost of renewables to the increasing economic and environmental costs of fossil fuels. In their article *Renewable Energy: Key to Energy Sustainability*, they predict that as oil supplies continue to dwindle, oil will be cost-prohibitive for much of the world. Coal remains abundant and cheap, but has lost public favor in recent years due to its harmful contributions to climate change. The authors describe how the renewable energy sector (solar and wind combined) is growing faster than any other energy sector. “Approximately US\$22 billion was invested in renewable energy worldwide in 2003. A recent report from the United Nations Environment Program (UNEP) suggests that investment capital flowing into renewable energy climbed from \$80 billion in 2005 to a record \$100 billion in 2006” (Asi, Muneer and Khan 2008, 2973).

As of 2008, renewable energy accounts for thirteen per cent of the world’s energy consumption (Asi, Muneer, and Khan 2008, 2971). Energy industry experts predict that by the year 2050, solar power has the potential to replace 1,286 coal-fired power plants and provide twenty-five per cent of our world’s energy needs (Richter *et al* 2009). By many indications, society is beginning a historic transition from a fossil fuel driven world to one powered by renewable energy. Academics have dubbed this the “New Energy Economy.”

In Africa particularly, solar energy has immense potential because the continent receives significant direct sunlight and human populations are far-flung (Sarr and Thomas 2005, 6). The distance between human populations makes transporting traditional, centralized electricity cost-prohibitive. A recent article in *Foreign Policy* states that the use of solar power in Africa increased 2,500 per cent between 1999 and 2005 (Foreign Policy 2009). “Research suggests that by tapping into just a small section of the solar energy resources of the Sahara desert, you could theoretically produce enough energy to fuel the entire planet” said Nick Nuttall of the UNEP in Nairobi (ESI-Africa 2008). Across the African continent, solar projects are sprouting up. Egypt, South Africa, Algeria, Morocco, Senegal, Mali and Kenya are a few of the African countries currently expanding their use of solar electricity.

Rural solar electrification programs are a classic example of technology leapfrogging. Leapfrogging is a international development term used to describe developing countries that use new technology to skip over the traditional phases of industrialization. Further clarification on this term is provided by Miedema (2008):

Leapfrogging does not necessarily mean that countries which are technologically weak will bypass the other countries hitherto in the lead. Often, technology leapfrogging means the catching up by skipping some of the intermediate technology stages. It can potentially lead to situations where the new technologies become dominant in developing countries while having a more complementary role in the economically more developed nations. The reason is that countries with large legacy systems can have inertia problems in switching to new technology systems. In countries with well-established infrastructures, new technologies are often implemented in manners complementary to the existing infrastructure elements. In countries with less developed infrastructures, new technologies may, to a larger extent, substitute older technologies.

By investing money in decentralized solar electricity, developing countries avoid the need to build centralized power plants and to string electrical towers and wires across their countries. Decentralized solar electricity has the added benefit of generating electricity from the sun rather than from fossil fuels. As the west struggles to transition from fossil fuel-generated electricity into the new energy economy, rural farmers living in mud huts in Senegal are already there.

2.2 Economic Impacts of Rural Solar Electricity

Given the relative newness of rural solar electrification programs, an insufficient amount of time has passed to effectively measure long-term economic impacts. In the 1997 study *Guide to Appropriate Electrification for Rural Areas of Developing Countries*, Anderson states the rural solar electrification programs *should* bring forth the development of cottage industries. However, Anderson goes on to say that electricity alone will not bring economic development. Rather, communities must also have “access to capital, raw materials, markets, a conducive legal and economic climate, and an entrepreneurial spirit.” Anderson clarifies that without these conditions, “electricity alone will result in little new business.”

In 2008 the World Bank published a report titled *The Welfare Impact of Rural Solar Electrification: A Reassessment of Costs and Benefits*. In this report, the World Bank exams the economic impacts of rural solar electrification through the lens of productivity. The report concludes that rural solar electrification has a “limited” impact on productive

activities. It explains that rural solar electrification has a greater impact on small, home enterprises than it does on medium and large-sized businesses. The study cites World Bank panel data from 1988 to 2003 demonstrating that “the number of home businesses grew significantly more in communities than became electrified than communities that did not or were already electrified prior to 1988” (World Bank 2008). However, the study failed to provide additional details regarding the panel data, such as where it was collected from, how it was collected, or what specifically it measured. Nor did the report include definitions of small, medium and large businesses. Without further details, it is difficult to assess the reliability of this data.

2.3 Environmental Impacts of Rural Solar Electricity

In developed countries, the term “renewable energy” is often used synonymously with “green” and “eco-friendly.” But in rural Africa, renewable energy projects do not replace fossil fuel driven electricity. Rather, they create new energy consumers. Thus, the question of how rural renewable energy project affect the environment is not as straightforward as it might seem.

In a study titled *Energy for Development: Solar Home Systems in Africa and Global Carbon Emissions* (2005), authors Duke and Kamman explore whether solar home systems reduce green house gas emissions in developing countries. The results of this study indicate that solar home systems do not directly reduce global green house gas emissions. “Even if the entire potential market of 400 million households receives solar

home systems, this would displace only approximately twenty million tons of carbon equivalent (tC) annually, or about 0.3% of global emissions” (Duke and Kammen 2005, 168).

Similarly, Amie Gaye of the United Nations Development Program states “current fossil fuel consumption levels in Sub-Saharan Africa are so low that an annual increase of ten per cent emission per capita will remain low – at levels below five per cent of those in industrialized countries.” (Gaye 2007).

On a more positive note, Duke and Kamman (2005) do establish that solar home systems deliver at least three “indirect carbon benefits”: solar home systems offset the need to expand conventional fossil-fuel powered centralized electricity; they displace the use of kerosene, batteries, and diesel generators; and they increase global demand for solar products thereby reducing prices for solar products. “Anything that boosts PV sales will cause a price reduction via the experience curve. This, in turn, will induce an increase in future sales levels that will further reduce PV prices along the experience curve” (Duke and Kamman 2005, 168).

In summary, the literature implies that rural solar electrification does not reduce global emissions of Carbon Dioxide, and therefore has only an indirect impact on climate change. As will be discussed in Chapter Three, rural solar electrification potentially has additional environmental impacts, such as its ability to reduce deforestation. However,

the available literature focuses solely on how rural solar electrification impacts climate change.

2.4 Social Impacts of Rural Solar Electricity

The electrification of rural communities in developing countries is bound to bring significant changes – both positive and negative – to traditional lifestyles. This thesis focuses on three specific subsets of social impacts: education, women’s empowerment, and community health.

2.4.a. Education

In 2006 Gustavsson published a study titled *Educational Benefits from Solar Technology*. This study, conducted in Zambia, finds that students with solar electricity spend more time on homework than students without solar electricity. However, the study also concludes that solar electricity does not result in improved academic performance. The study highlights additional correlations between education and electricity. It finds that urban teachers are more willing to relocate to rural areas that had solar electricity. This is significant because it is often a challenge to find qualified teachers in rural areas. The study also finds that teachers with solar electricity in their homes are able to offer evening tutoring to their students and are better able to prepare for the next days lessons. According to the study, schools with solar power often were used for community activities, such as women’s literacy classes. Ironically, the study finds that the most

common applications of solar electricity were watching television and listening to music (Gustavsson 2006).

2.4.b. Women's Empowerment

According to the Solar Electric Light Fund (2003), an international non-profit organization headquartered in Washington, D.C., “energy in the rural, developing world is inextricably a women’s issue.” In developing countries, women are responsible for the majority of household chores, including but not limited to: collecting and carrying water and firewood; cooking meals over fire for large families; washing, drying and ironing all clothes; cleaning homes; shopping in the local market; and caring for children.

Oftentimes, women are also responsible for food production and preparation, including but not limited to: vegetable gardening; fruit orchard cultivation; de-husking and grinding of agricultural products; and tending to small farm animals such as goats and chickens.

In many parts of the world, women are the first to wake in the morning and the last to go to bed in the evening. Women in developing countries are often caught in a cycle of poverty; being too restricted by household responsibilities to participate in income generating activities or educational activities. Manual labor and frequent child birth burden women’s long term health. Electric-powered machines potentially could reduce the amount of time women spend on household chores, thus reducing their physical exhaustion and freeing them from the cycle of poverty.

There are few studies that focus exclusively on women's empowerment. In Gaye's (2007) study, titled *Access to Energy and Human Development*, the benefits of electricity on women are described primarily in health terms. Using electricity to cook reduces back injuries resulting from carrying heavy loads of firewood long distances. This study also asserts that women benefit from decreased risk of sexual assault when they cook with electricity, because they no longer traveling long distances to collect firewood. In Anderson's (1997) study, the author raises the point that sometimes electricity can lead to increased household chores, citing a study by Nafzinger (1990) in which women spent more time cleaning after getting electricity, presumably because they were better able to see that which needed cleaning.

2.4.c. Community Health

Solar electricity is considered by many as a healthier way to generate electricity than burning fossil fuels (Haines and Kammen 2006). Direct impacts of solar electricity on human health include: reduced eye and lung problems, reduced risk of fire, and lower fertility. Lower fertility may be considered a health benefit in countries where women's health is negatively impacted by a high number of pregnancies. Indirect impacts of solar electricity on human health include: increased willingness of health professionals to relocate to rural areas and increased dissemination of health news via radio and television.

According to Gaye, using kerosene lanterns indoors and cooking with wood indoors creates indoor air pollutants (IAPs). IAPs are responsible for the death of 1.8 million people per year, double the number of people who die each year from malaria (Gaye 2007). “Research has also shown that carbon monoxide, one of the compounds in wood smoke, reduces pregnant women’s placental blood flow, making it more likely for her to bear an underweight baby” (Gaye 2007).

Anderson’s study (1997) references a 1988 study by Nazrul Hoque titled *Rural Electrification and Its Impacts on Fertility*. Hoque’s study indicates that fertility decreases in rural areas as electrical consumption rises. Although both Anderson and Hoque offer multiple explanations for this, both agree that in general, electricity “decreases the rewards and increases the costs of having a large family.” The World Bank study referenced in section 2.2 also provides information on the correlation between electricity and lower fertility. In this study, lower fertility results from increased awareness of birth control methods. According to the World Bank study, women are learning more about birth control through television (World Bank 2008).

2.5 Concerns with Rural Solar Electrification Programs

An analytical review of available literature on rural solar electrification produces some areas of concern. Namely, rural solar electrification programs worldwide lack sufficient monitoring and evaluation, and they cost more money while producing less electricity

than centralized electrical power stations. Additionally, some authors express concerns about the distribution of benefits of rural solar electrification programs.

2.5.a. Decentralized Solar Systems Lack Monitoring and Evaluation

While the future of renewable energy in Africa is bright, there is a recurring concern in the literature that little has been done to monitor and evaluate renewable energy projects after installation. “In West Africa, at least, there has been very little feedback on (solar) experiences that could be used to inform renewable energy technology promotion policies. Projects proceed one after another without decision-makers really taking account of or deploying the knowledge gained to date” (Sarr and Thomas 2005, 11). Sarr and Thomas explain that evaluations of solar programs are uncommon because most projects are donor-funded. This follows the old adage of not looking a gift horse in the mouth. In an article titled *Senegal’s Ambitious Solar Power Project Mismanaged*, the solar projects in the Fatick region are allegedly experiencing problems. “Poor planning, maintenance and technical support are amongst the factors that threaten to undermine an ambitious effort to electrify Senegal’s remote Sine-Saloum Delta using solar energy. Another major problem is people’s lack of willingness or ability to pay the fees for the photovoltaic systems” (Integrated Regional Information Network 2008).

“The outcome of the Sine-Saloum (Fatick) project is terribly important,” said Bob Freeling, executive director of Solar Electric Light Fund. “If projects like these run into

sustainability problems, there will be negative repercussions for a lot of industry players” (Ibid.).

The importance of program monitoring and evaluation cannot be overstated. Without monitoring and evaluation, those who lead rural solar electrification initiatives are unable to measure the success of these programs and are unable to identify areas for improvement. By failing to do monitoring and evaluation, an organization gives the impression that the installation of solar electrical systems is more important than ensuring that these systems are successfully achieving their intended goals and objectives.

Ideally, all rural solar electrification programs should incorporate participatory monitoring and evaluation (PM&E). According to Jackson (1995), PM&E is defined as “a process of evaluation of the impacts of development interventions which is carried out under the full or joint control of local communities in partnership with professional practitioners.....Community representatives participate in the definition of impact indicators, the collection of data, the analysis of data, the communication of assessment findings, and, especially, in post-assessment actions designed to improve the impact of development interventions in the locality.”

2.5.b. Decentralized Solar Systems Lack Cost Effectiveness

To someone unfamiliar with rural solar electrification programs in Africa, it would be easy to assume that solar energy is free once the equipment is installed. But most rural

solar electrification programs do not work that way. Rural residents receiving solar equipment typically agree to pay a flat, monthly fee similar to a monthly electric bill. These fees are typically used to repay the upfront costs of the solar equipment.

In a 2007 study titled *Solar Home System Electrification as a Viable Technology Option for Africa's Development*, Wamukonya calculates that decentralized solar electricity in Africa costs \$0.08 to \$0.14/kWh, whereas traditional electricity in rural Africa costs \$0.02 to \$0.04/kWh. Per these calculations, decentralized electricity is two to four times more expensive than centralized electricity. Ironically, rural Africans typically have lower income and are therefore less able to pay for electricity than their urban counterparts.

Although decentralized solar electricity is more expensive than centralized grid electricity, it supplies less electricity per home. As described in Chapter One, a typical solar home system can power a small fan, a few light bulbs, and a small television. It cannot be used for an air-conditioner, washing and drying machines, or other large, energy-intensive machines. It cannot be used to power a small home business.

Decentralized solar electricity can also be more expensive than decentralized diesel-generated electricity. In 2008, Zaida Contreras of the University of New South Wales conducted an economic analysis on four means of producing electricity in rural Senegal: diesel mini-grids, photovoltaic mini-grids, hybrid generators, and solar home systems. She published her findings in the *International Journal of Energy Sector Management* in

an article titled *Planning Paths for the Electrification of Small Villages using Decentralized Generation: Experience from Senegal*. Contreras concludes that solar systems are only more cost effective than diesel systems under very specific conditions: in communities with fewer than five hundred residents, located at least 5.4 kilometers from the central transmission electrical grid, and in which residents could successfully work out a method for sharing electricity. For any community unable to meet the above criteria, diesel-generated electricity was more cost effective.

Many rural Africans – accustomed to hearing politicians promise the delivery of centralized electricity when elected – simply consider decentralized solar electricity as a poor and expensive substitute for centralized electricity. According to Duke and Kammen (2005), “rural South Africans generally view solar home systems as a second-best option relative to heavily subsidized grid connections that would provide them with considerably better service for similar or lower monthly payments.” While some may argue that solar electricity is better than no electricity, rural solar electrification projects are unlikely to succeed if not embraced by local populations. “It is stressed that a knowledge of local conditions and needs, an accurate assessment of energy resources, technical and economic vulnerability, and social acceptability, are prerequisites for solar energy systems to play a successful role in rural development” (Bassey 1987).

2.5.c. Distribution of Benefits

Another concern identified in the literature review is that rural Africans and their governments may not be the ones benefiting the most from rural solar electrification programs. In her study, Wamukonya (2007) describes misconceptions about the international funding of rural solar electrification projects. In most of these projects, she claims, international donors provide six to fifty percent of the project funds. In many cases, the other fifty to ninety-six per cent of funding comes from the host country. The host country may take out a loan from the World Bank to pay for rural solar projects, assuming that over time it can repay these loans with collected user-fees. This becomes problematic when those benefiting from the solar equipment stop paying their monthly fees. Sometimes they stop paying their fees because they cannot afford to pay them, and other times people stop paying their monthly fees because their equipment has broken down and no technicians are available to repair it. Regardless, when this happens, it is the government who is left holding the bill. This situation often contributes to increased debt for the governments of many developing countries.

Another noteworthy point from Wamukonya's study is that while less than half of the funding is coming from international donors, it is common for the donors to place conditions on the loans (Wamukonya 2007). For example, lenders might designate which company will provide the solar equipment. And given that ninety percent of solar equipment is manufactured in Western countries, one wonders if there is a symbiotic relationship between the donor and the manufacturer (Ibid.).

As explained in section 2.5.b., there may be more cost effective ways to deliver electricity to rural Africa. If this is true, then one might wonder why many African governments support and promote solar technology. Wamukonya believes that solar projects are more likely to attract funding than other electrification projects because solar projects have a green image. By transferring green technology to developing countries, western countries qualify for Clean Development credits under the Kyoto Protocol. Thus, the international community is less willing to support traditional electrification programs, even when research indicates that rural residents may benefit more from and strongly prefer centralized electricity. The international community is more willing to fund high-tech solar electrification programs because they are green, even when such programs deliver only limited environmental benefits to rural recipients. This is where the notion of green washing comes into play. There is little value in promoting green technology if it does not deliver positive environmental impacts.

In conclusion, the literature review showcases both the excitement and apprehension associated with rural solar electrification programs in Africa. The information provided in this literature review sheds some light into the complexities of rural solar electrification and lays the background for the data presented in Chapter Four. Before presenting the data, however, Chapter Three provides background information on the methodologies used to collect the data.

CHAPTER THREE METHODOLOGY

3.1 Research Question

This study seeks to measure the educational, environmental, and social impacts of rural solar electrification in the Fatick region of Senegal. The purpose of measuring these impacts is to determine what role rural solar electrification programs play in international development. Given the positive relationship between electrification and development, as described in Chapter One, a natural hypothesis might be that rural solar electrification programs assist countries in the development process and are a model of technology leapfrogging. However, concerns about rural solar electrification highlighted in the literature review caution development practitioners from drawing this conclusion without actually measuring the impact of these programs. Thus, the purpose of this study is not to test one specific hypothesis or another, but rather to collect and measure qualitative data in order to evaluate effectiveness and draw useful conclusions.

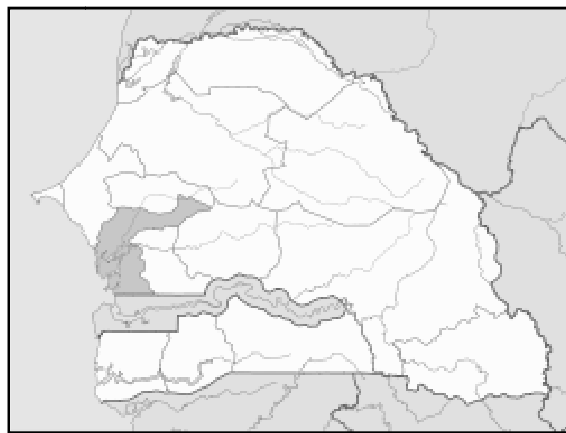
3.2 Selection of Research Location

I selected Senegal as the location for this study primarily due to my familiarity with the country. Having lived in a rural village in the Fatick region for three years, my understanding of the culture, lifestyles and languages provides a solid framework against which to compare the findings of this study.

West Africa in general, including Senegal, consumes less electricity than any other region in the world (Sarr and Thomas 2005, 8). Thus, rural solar electricity potentially could have the most significant impact in this part of the world. Within West Africa, Senegal is one of the few countries where a “definite renewables market structure is starting to take root” (Sarr and Thomas 2005, 11). Long considered the “most stable democracy in West Africa,” Senegal is poised to serve as a renewable energy leader and role model for the region and the continent (Central Intelligence Agency 2009).

This study is limited to the Senegalese region of Fatick – one of the poorest regions in Senegal. According to Sarr and Thomas (2005), poverty rates in this region reach up to eighty per cent. The region of Fatick is divided into three departments: Foundiougne, Fatick, and Gossas. This study specifically focuses on the department of Foundiougne.

Figure 4. The Region of Fatick, Senegal



source: Wikipedia

Figure 5. The Three Departments with the Region of Fatick



source: [Wikipedia](#)

Note: Foundiougne is misspelled in Figure 5.

The Region of Fatick, and in particular the department of Foundiougne, play a critical role in the ecology of Senegal. Two eco-regions collide in the Fatick region: the Sahelian Acacia Savanna and the Guinean Forest-Savanna. The Sahelian Acacia Savanna forms the southern border of the Sahel, to the north of which lies the Sahara Desert. The arid Sahelian Acacia Savanna is characterized by small, thorny *Acacia* trees and sandy, dry soils. Subsistence farming is possible but difficult in this environment. Because rural Senegalese cook with fire wood, the forest cover in the Sahel visibly diminishes year by year, welcoming the Sahel and the Sahara Desert further into Senegal's borders. The Guinean Forest Savanna eco-region stands in stark contrast to this desertification. Characterized by moist, red soils and broad-leafed trees, this eco-region forms the northern border of the more tropical Guinean Forest Zone. This eco-region supports more productive agriculture and richer biodiversity. From an environmental perspective, the region of Fatick is a critical battleground in Senegal's fight against desertification.

The ecological health of this region is heavily influenced by the local practice of collecting wood to cook food. If solar energy were used in this region to replace traditional open-fire cooking, it would have immense environmental benefits on the region and the country. In summary, this study focuses on the region of Fatick because it stands to benefit ecologically and economically from rural solar electrification.

3.3 Research Design

To adequately assess the impact of rural solar electrification projects in Senegal, I designed a cross-sectional research project. Using a survey, I collected primary, qualitative data during a four-week period from a cross-section of the Fatick population.

Individuals who have directly experienced rural solar electrification are a reliable source of information on the impacts of Senegal's rural solar electrification programs. Thus, the units of analysis in this study were rural Senegalese people in the department of Foundiougne within region of Fatick who currently have, or recently have had, solar electricity in their home.

The most effective method for collecting information from the units of analysis was in-person interviews. Written surveys were impossible for a variety of reasons: many rural Senegalese are illiterate; there are no specific addresses or mailboxes to mail surveys to; and due to the high number of languages in Senegal, it would be difficult to know which language(s) to use in written surveys. Telephone surveys would have been impractical as well. Although many rural Senegalese have access to public pay phones or cell phones,

most households do not have individual telephones. Additionally, there are not telephone books that cover rural Senegal, so obtaining phone numbers would be nearly impossible. E-mail surveys would also fail because many Senegalese are unfamiliar with using the Internet and do not have e-mail accounts.

Although I wanted to travel to Senegal to conduct in-person interviews, I concluded that the participants might be more comfortable sharing information with another Senegalese person. Additionally, I thought this might minimize possible cross-cultural miscommunications. Thus, I hired two Senegalese research assistants to conduct the interviews: Lamine Seydi and Seneke Sarr. Seydi is an electrician from the capital city, Dakar, who is fluent in Wolof and French. His understanding of electrical systems added to the technical accuracy of the research. Sarr is a resident of the Fatick region who speaks Wolof, Serere, and Pulaar. His familiarity with the people and languages of the region complimented Seydi's technical knowledge.

From mid-August 2009 to mid-September 2009 Seydi and Sarr traveled to ten villages in the Fatick region to conduct in-person interviews. For every interview, they used the same survey questions. Interviews were conducted in a variety of languages, and each interview was recorded on an audiocassette. Once all of the interviews were recorded, Seydi and Sarr mailed the cassettes to me in the United States via a secure courier service. Upon receipt of the audiocassettes, I transcribed and translated each interview with the help of Youssoupha Diatta, a Senegalese-born local resident. I entered all data into a

simple excel spreadsheet, which facilitated the sorting, comparing and analysis of data. A summary of the data is found in Chapter Four.

3.4 Survey Design

The survey was initially designed in English. I compiled a list of survey questions, grouping them together into the following categories: general background information, economic impacts, social impacts, environmental impacts, and overall impressions. The general background section included basic demographic information about each participant, such as their gender, age and household size. This section also included several questions about the participants past experience with solar electricity; such as what type of solar system they had and who provided maintenance work on the system. In total, there were fifteen questions under the general background section.

The economic impact section of the survey included four questions. As a culture, Senegalese do not openly discuss financial matters. Thus, I tried to include questions that might measure economic improvement from a variety of angles. For example, participants were asked if solar electricity helped them to: generate income, save money, or purchase new property.

To measure social impacts, questions focused on education, health and women's empowerment. Participants were asked if solar electricity was being used in community

schools and health centers. They were asked how solar electricity affected their school-aged children. Participants were also asked about women's literacy classes.

The fourth section focused on the environmental impacts of solar energy. Participants were asked questions regarding their consumption of petrol, batteries, diesel fuel and wood for cooking.

The survey concluded by asking participants to provide general feedback about solar electricity. This final question was intentionally created as a very open-ended question, with the hopes of capturing additional data missed in the impact-specific sections described above.

Once all questions were drafted, I reviewed the proposed list of survey questions with Youssoupha Diatta. As a Senegalese man living in the United States, he was able to point out which questions might be confusing in the Senegalese culture. Based upon his suggestions, I edited many of the survey questions, and then translated them into French. I e-mailed the French version of the survey to the research assistants in Senegal. Upon their receipt of the survey, we reviewed the questions over the telephone to ensure that the research assistants thoroughly understood each survey question. A full list of survey questions in English is available in Appendix A. The French translation of the survey questions is provided in Appendix B.

3.5 Participant Selection

Residents of the Fatick region are clustered into villages and small towns. Within the region there are nine small towns: Foundiougne, Fatick, Passy, Sokone, Toubacouta, Missira, Samba Gueye, Sirmang and Karang. These small towns have centralized electricity. There is one paved road that transects the region and connects these towns. Power lines follow the path of the paved road. A few, large villages that bump up to the road also have electricity, but none of the off-road villages have centralized electricity. Villages vary greatly in population size, ethnic composition, and proximity to other villages.

Most of the solar electrification projects described in chapter one were implemented on a village-by-village basis. Thus, rural Fatick can be easily divided into groups of villages with solar electricity and villages without solar electricity. Because of this natural grouping, it made the most sense to first select villages to interview, and secondarily to select individuals within selected villages.

For my sampling frame, I attempted without success to obtain a list of all Fatick solar villages from the Agence Senegalaise d'Electrification Rural (ASER), the Senegalese government agency tasked with rural electrification. When this method failed, I asked the research assistants to select villages based on their knowledge of the region.

Although there is value in randomly selecting villages from the sampling frame, I decided to forego this method in favor of collecting information from a balanced variety of villages.

I asked the research assistants to select villages based on comparative population size and ethnicity. I requested a balanced number of large, medium and small villages, and a balanced number of Wolof, Pulaar, Serere, Mandinka, and mixed villages. I intentionally wanted participants to be from different types of villages, as differences in village size and ethnic group may affect people's experiences with solar electricity. The below chart provides information on the ten participating villages. A map showing the location of each village is below in Figure 6.

Table 4. Participating Village Profiles

Village Name	Village Size	Ethnicity
Touba Mouride	Large	Wolof
Keur Aliou Gueye	Large	Mixed
Keur Mama Lamine	Large	Mixed
Keur Malick	Medium	Wolof
Simon Diene	Medium	Serere
Daga Babou	Medium	Serere
Padanem	Small	Pulaar
Keur Layéne Sosé	Small	Mandinka
Taba N'ding	Small	Mandinka
Daga Diawdine	Small	Serere

Figure 6: Locations of Participating Villages in the Department of Foundiougne



Within each village, the research assistants randomly selected eight to nine adults. They were asked to do their best to balance the number of men and women interviewed, and to interview people from a variety of age groups. Once identified, each participant was given an information sheet and a brief verbal explanation of the study.

CHAPTER FOUR DATA AND ANALYSIS

To effectively present and analyze the quantitative and qualitative data collected from eighty-one in-depth interviews, this chapter is organized into six sections. Section one examines data related to the administration of rural solar electrification programs in the Fatick region of Senegal. The second, third and fourth sections focus on measuring the economic, environmental, and social impacts of rural solar electrification, respectively. The fifth section reviews customer satisfaction with solar electricity, while the sixth section addresses the limitations and delimitations of this study. Conclusions drawn from the data are presented at the end of the chapter.

4.1. The Administration of Rural Solar Electrification

To appropriately frame the economic, social and environmental impacts of Senegal's rural solar electrification, it is necessary to first understand the context in which rural solar systems operate in the Fatick region of Senegal. This section explores what types of solar systems Fatick residents are using, the applications and limitations of these solar systems, and the fee structure of these solar systems.

4.1.a. Types of Solar Systems Employed in the Fatick Region

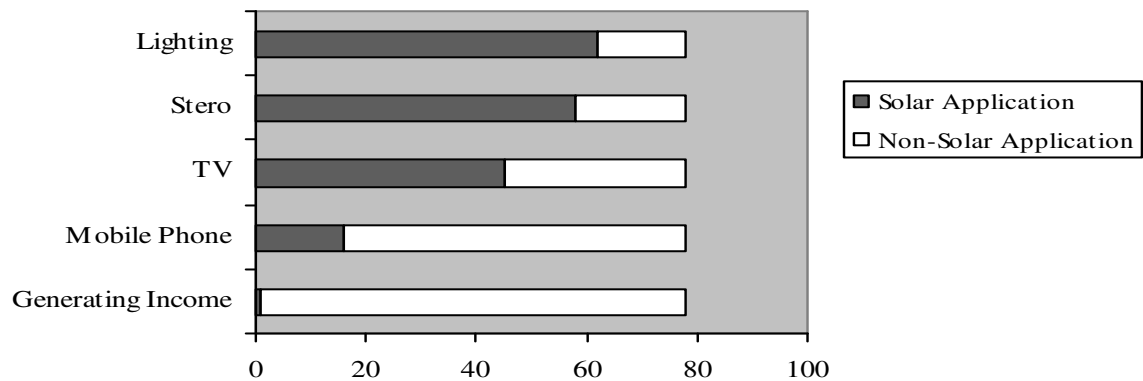
As described in chapter one, there are various models of solar systems; mini-grids, solar home systems, and solar-diesel hybrid systems. To determine which systems are being

used in the Fatick region, research assistants asked participants what type of solar system they have. In the ten villages surveyed, one hundred percent of participants reported having solar home systems. There were no reports of hybrid systems or mini-grids. Although this was not anticipated in the research design, this simplifies the data analysis, given that there are no cross-system comparisons to perform. This also implies that solar home systems are the most common form of rural solar electrification in Senegal's Fatick region.

4.1.b. Applications of Solar Systems in the Fatick Region

To determine common applications of solar electricity, participants were asked how they use solar electricity. This question was specifically designed as an open-ended question so as not to prompt or limit specific responses from participants. As illustrated in the below graph, participants reported using solar electricity for lighting, radio, television and charging mobile phones. Participants typically cited multiple applications, hence the total responses below exceeds eighty-one. One participant reported using solar electricity to light her small village store, which is classified as an income-generating application.

Figure 7. Reported Applications of Rural Solar Electricity

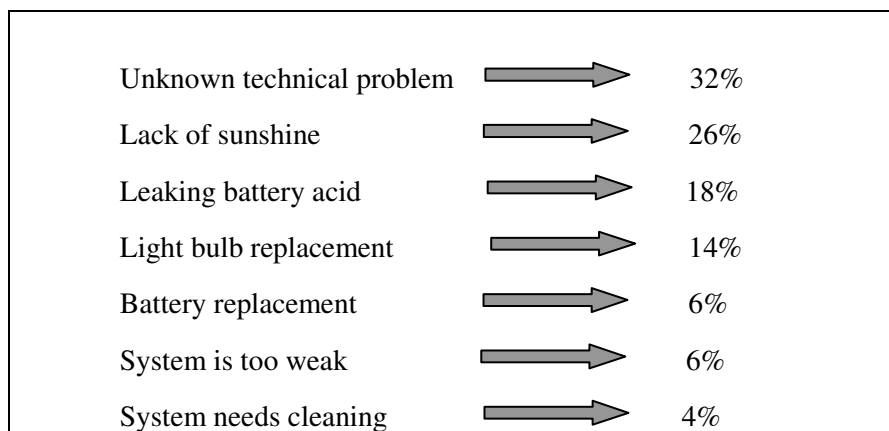


In analyzing the data, it is noteworthy that twenty percent of respondents did not report using solar electricity for lighting. While this may be accurate, it is more likely that these participants simply forgot to include lighting in their response. This points to a weakness in the survey design. Results may have been more accurate if the question had been divided into multiple sub-questions asked about specific usage, such as *Do you use solar electricity for lighting*, *Do you use solar electricity for charging your mobile phone*, and so on. It is also surprising that only twenty percent of participants reported using solar electricity to charge mobile phones. According to the World Bank, forty-four percent of Senegalese had cell phones in 2008 (World Bank 2010). This may be another example of participants not comprehensively stating all major and minor solar applications. Alternatively, it is possible that some villages are located in low or no reception areas, and therefore have fewer cell phone owners.

4.1.c. Limitations of Solar Systems

In addition to understanding how consumers use solar electricity, it is important to understand the limitations of usage. Participants were surveyed about system breakdowns and maintenance. Of those who responded, eighty-nine percent reported having service problems with their solar home systems. Figure 4.2 below illustrates the most common responses:

Figure 8. Reported Limitations of Rural Solar Electricity



The specific limitations above highlight the challenges of installing a high-tech system in a low-tech community. The most common response was an unknown technical problem. The second most common response was a lack of sunshine. Lack of sunshine, of course, is not the actual problem; but rather the ability of the battery to store the sun's energy. Even something as seemingly simple as changing a light bulb can be intimidating to a person unaccustomed to using light bulbs.

One participant described a training his village received on basic maintenance of solar home systems. "We were taught how to wipe it out and clean it ourselves. We know

how to climb the pole, wipe out the battery clean when it is dirty.” This is a good example of a best practice that could be shared with other communities receiving solar electricity. The majority of participants indicated that there is a specific maintenance person assigned to their village. Sixty-two percent of participants were able to identify their maintenance person by either name or village of residence. Only three participants had negative comments about their maintenance person; two of which were complaints over high fees for maintenance service. Interestingly, these results seem to contradict the numerous reports of a lack of trained maintenance technicians in rural area, as mentioned in chapter two.

4.1.d. Solar Fee Structures

In addition to collecting information on the applications and limitations of Senegal’s rural solar home systems, it is helpful to understand how much money households spend on this technology. The cost of rural solar electricity directly influences how many people use it, and therefore affects the impact of rural electrification. For this study, participants were asked how much money they pay and how frequently they pay for their solar electricity. The below chart summarizes the responses grouped by village.

Table 5. Reported Solar Fee Schedule

Village	Installation	Monthly	Annual Target Amount	Collection
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	Fee	Installment		Frequency
Daga Babou	20,000 CFA	Unspecified Amount	30,000 CFA	Irregular, unscheduled visits
	\$39 USD*		\$58 USD	
Daga Diawdine	None	Unspecified Amount	30,000 CFA	Irregular, unscheduled visits
			\$58 USD	
Keur Aliou Gueye	None	Unspecified Amount	Unspecified Amount	Irregular, unscheduled visits
Keur Layene Soce	None	Unspecified Amount	30,000 CFA	Irregular, unscheduled visits
			\$58 USD	
Keur Malick	None	6000 CFA	72,000 CFA	Irregular, unscheduled visits
		\$12 USD	\$140 USD	
Keur Mama Lamine	None	Unspecified Amount	50,000 CFA	Irregular, unscheduled visits
			\$97 USD	
Padanem	None	Unspecified Amount	30,000 CFA	Irregular, unscheduled visits
			\$58 USD	
Simon Diene	None	Unspecified Amount	Unspecified Amount	Irregular, unscheduled visits
Taba Nding	None	5000 CFA	60,000 CFA	30,000 CFA collected every 6 months
		\$8 USD	\$117 USD	\$58 USD
Touba Mouride	None	Unspecified Amount	Unspecified Amount	Irregular, unscheduled visits

* Note: USD amount was calculated using the public exchange rate of 514 CFA = \$1 USD, dated from May 10, 2010. This exchange rate varies on a daily basis.

Interestingly, the amount that households spend on solar electricity varies significantly between villages – from \$58 to \$140 per year. From a Western perspective, this annual cost may appear inexpensive. But when calculated as a percentage of average annual income in Senegal, these annual expenses look very different. According to the World Bank (2010), the per capita gross national income (GNI) for Senegal in 2008 was \$980. If this number is accurate, then spending \$58 to \$140 annually on solar electricity

represents six to fourteen percent of annual income. Given that the populations surveyed are rural subsistence farmers in one of the poorest regions of Senegal, it is likely that their average annual income is significantly lower. One participant indicated that farmers in the Fatick region earn an average of 200,000 CFA to 250,000 CFA per year. This translates to \$389 - \$486 USD per year. If this is an accurate estimate, then participants are spending twelve to thirty-six percent of their annual incomes on solar electricity. To put these percentages into perspective, this would be comparable to a family in the United States with an annual income of \$50,000 spending \$6,000 - \$18,000 each year on its electric bill.

In addition to an annual fee, survey participants from one community indicated that they had to pay an installation fee of 20,000 CFA, or approximately \$39 USD.

When asked how the annual fee is collected, participants from two villages stated that they have a flat monthly fee. However, only Taba Nding reported that their flat monthly fee was regularly collected on a bi-annual basis. Most participants said that money collectors appear at random intervals in the village and demand a cash payment on the spot. No advanced warning of these collection visits is given. Participants explained that they are expected to pay a specific annual amount, and they just pay what they have on hand whenever the collectors appear. If a family has nothing to offer the collectors, then they are expected to have a higher payment the next time the collectors appear. If the collectors determine that a family is not paying enough, the collectors remove or disable the solar home system. Overwhelmingly, participants expressed frustration over this fee

collection system. The follow box displays some direct quotes recorded during this project.

Figure 9. Direct Quotes on Solar Fee Schedules

- *There is no price. They just stop by out of the blue and you just give them what you have. Either they accept it or they take your solar panels away.*
- *They didn't tell us a price. Sometimes they would stop by and ask for money. One day they came out of the blue and asked me for 20,000 CFA (\$39 USD). I didn't have it, so they took the solar panels away.*
- *It used to be every month, but the collectors would not always come. When they would come, they would ask you for the equivalent of how many months they had not collected. You give them what you have. If it's not enough, they decide if they should take the panels away or come back to get more money.*
- *The person who talked to us about it first lied to us. He said we only had to pay 30,000 (~\$58 USD) CFA to keep it. Then he came back again and said now we have to pay 30,000 CFA every year, or else they will take it away.*
- *The only thing I don't like about it is that they are not regular on the deadline for collecting money. They should give us specific dates and stick to it; that way we can be better prepared.*
- *In some ways it is like a payment with no end. These people just show up anytime and ask for money and whatever we have we give them. But we don't know when the payment will end or when we will be free. Many people who are not able to make that payment whenever the people show up, they end up taking away their solar panel.*

Although the vast majority of participants expressed frustration at the irregularity of the fee collection, one participant indicated that the flexibility of the payment structure was intended to help the farmers, who earn most of their annual income when they sell their crops at the end of the growing season. “At first it was understood that we had to pay 6,000 CFA (\$12 USD) per month, but that changed because as farmers we could not

afford that because we don't make money on a monthly basis. So whenever they stop by, we just give them whatever we have in our pockets." Thus, the fee collection program may be intentionally designed as flexible so that farmers can pay what they can when they can. While participants may appreciate this flexibility, they also conveyed a desire for a more organized and transparent collection system. Collectors appear to have wide discretion in deciding who keeps their solar home systems. The entire collection system seems designed for exploitation.

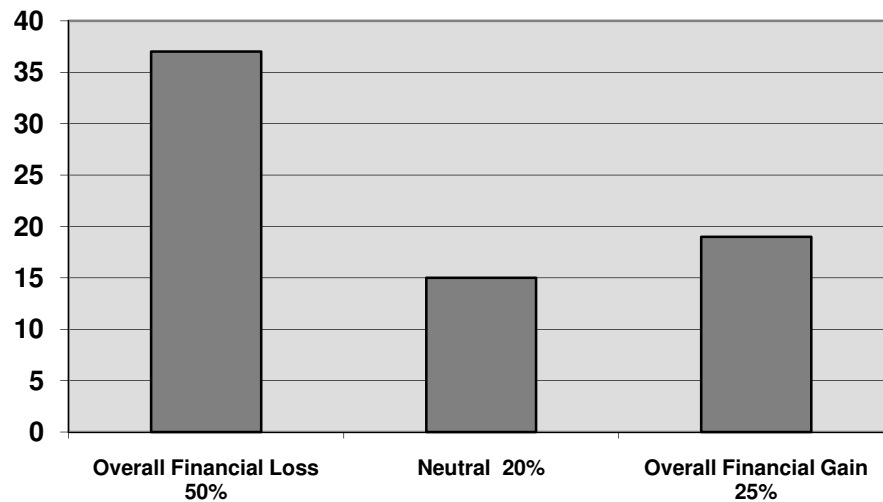
4.2 Economic Impacts of Rural Solar Electrification

In a cash culture that does not openly discuss money, such as Senegal, it can be difficult to measure the economic impacts of rural solar electrification. For this study, the goal was not to measure precise economic gains and losses. Instead, the goal was to establish a general sense of whether or not rural solar electrification is leading to improved economic conditions on a household level. To this end, participants were asked general economic questions.

4.2.a. Economic Gains and Losses

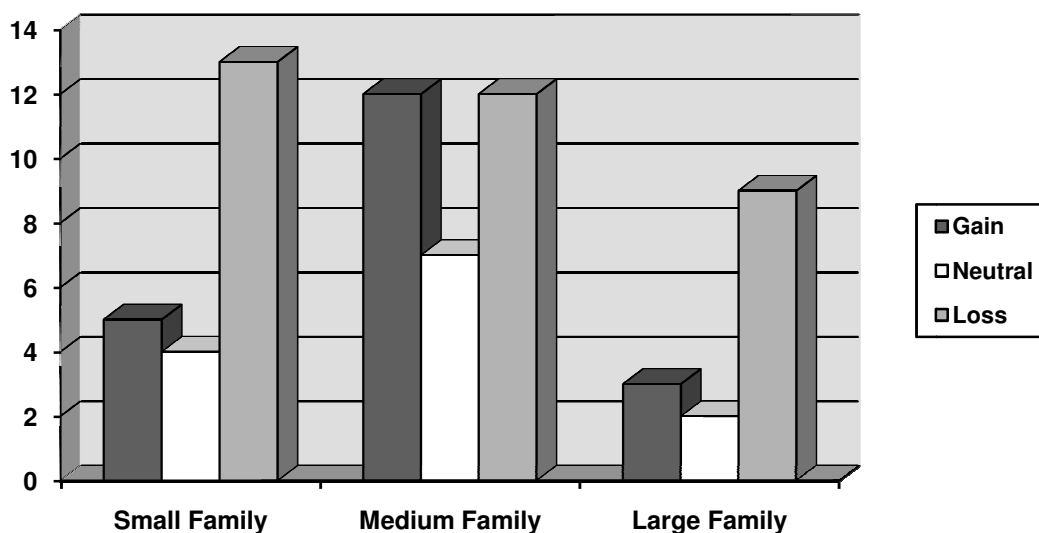
The first question participants were asked was whether they had gained or lost money since getting solar electricity. Half of the participants reported losing money. Twenty-five percent of participants reported gaining money. Twenty percent said that they neither gained nor lost money. The remaining five percent provided unrelated responses.

Figure 10. Post-Installation Financial Gains and Losses



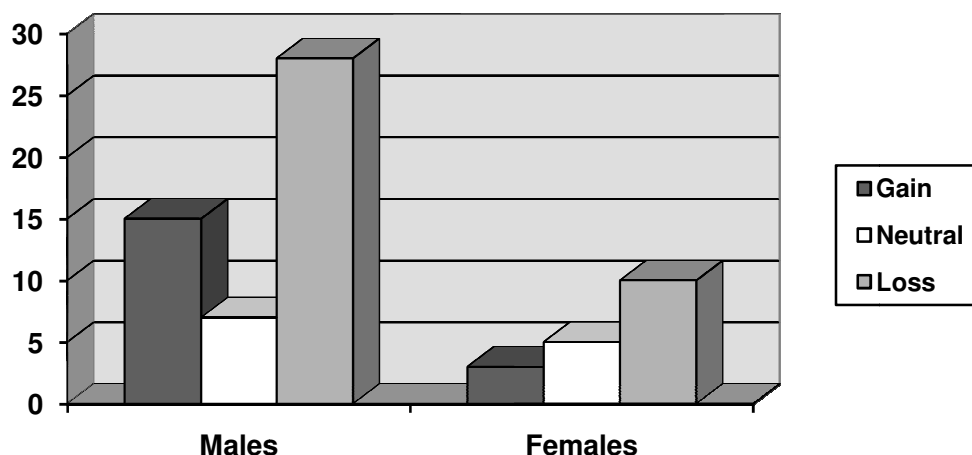
The data from this question does not produce any noticeable trends. Some participants said that they spend more each year on their solar payments than they did on other energy sources, such as petrol or batteries. Other respondents reported spending far less on solar than on other energy sources. This draws attention to strong possibility that different households have different consumption levels. To test if household size might be an influencing factor, data was sorted into three groups; small households (ten or fewer residents), medium households (eleven to twenty residents), and large households (twenty-one or more residents). The below chart depicts the specific results of this data sorting. The only notable trend is that small and large households predominantly reported a financial loss after the installation of solar home systems, whereas medium sized families are evenly divided in their reported gains and losses. This may indicate that the solar home systems currently in use in the Fatick region are best-suited for medium-sized families. However, additional research would be needed to make such a determination.

Figure 11. Economic Impacts of Rural Solar Electrification by Household Size



With still no clear trends regarding financial gains and losses, the data was re-sorted into gender-based groups. This sorting was motivated by the possibility that men and women may profit differently from solar electrification. The results indicated that while the majority of participants reported overall financial losses, a higher percentage of male participants reported financial gains. Sixteen percent of female participants reported financial gains, whereas thirty percent of male participants reported financial gains. There are multiple possible explanations for this trend. In Senegal, adult women are traditionally less educated than men, and women are less likely to seek employment outside of the home. Thus, as a whole, men have a higher tendency to earn income than women.

Figure 12. Economic Impacts of Rural Solar Electrification by Gender



4.2.b. Property Acquisition

Another possible indicator of economic development in rural Senegal is the acquisition of new property. Like many farmers in developing countries, rural Senegalese farmers are more likely to invest profits into livestock, land, farming equipment, cars, or houses than in bank accounts. The survey asked participants if they had purchased any property since gaining their solar home systems. Of those that responded, ninety-six percent said that they had purchased no new property. Several respondents found this question humorous, clarifying that the electricity generated by solar home systems is very weak. It cannot power all of the appliances that families would like to power, and it certainly cannot power appliances for small income-generating activities. One respondent was upset by the question, and stated “No, it wastes my money. I cannot do anything with it, I cannot do any work.” Not all responses were negative. Three participants said that they have purchased new property: one zinc roof, one bicycle, and the third did not specify what his new property was.

4.2.c. Equipment Acquisition

Although only four percent of participants reported buying new property, fifty-five percent of participants reported buying new equipment since gaining solar electricity. Specifically, forty-eight percent reported buying a television; twenty-one percent reported buying radios; and five percent reported purchasing mobile phones. This data coincides with the data in 4.1.b. regarding common uses of solar electricity. Data in section 4.1.b. indicated solar electricity is being used primarily to power common household equipment rather than being used to generate income.

4.2.d. Productivity

Another survey question asked participants if having solar electricity saved them time. Logically, if people have more time, they may be able to invest that time in productive activities. Unfortunately, the research assistants neglected to ask this particular question to most participants. Of the eighty-one participants interviewed, only fifteen people were asked if having solar electricity saves them time. Of the fifteen responses, nine said yes and six said no. One person enthusiastically said “It does! I don't do as many trips to the boutique for petrol anymore.” When asked why they did not ask this question to most participants, the research assistants stated that the question did not make sense.

In summary, the data indicates no significant economic gains results from the rural solar electrification programs. The majority of participants reported that solar electricity has not helped them generate income. There appears to be no correlation between solar

electricity and the purchasing of new property. The only apparent economic impact of the solar electricity is that the majority of solar consumers purchased electronics, such as TVs and radios.

4.3 Environmental Impacts of Rural Solar Electrification

Solar energy is typically considered a green technology that is good for the environment. While this is certainly true in cases where solar energy replaces fossil fuel driven energy, this may be presumptive when solar energy is being used to create new energy consumers. Very little research has been done on the environmental impact of rural solar electrification projects in developing countries. This study attempts to measure the environmental impact of rural solar electrification by surveying how it has affected participant's usage of petrol, batteries, generators, and fire wood. The data from all four questions has been combined into Figure 4.8 below.

4.3.a. Petrol Consumption

When asked if their petrol usage had increased or decreased since getting solar electricity, none of the participants reported an increase in petrol usage. Ten percent of participants said that their use of petrol had decreased, while ninety percent said that they no longer use any petrol at all. One person responded with "Petrol? I cannot tell you the last time I even saw petrol." Recent corresponding data from the World Bank indicates that Senegal's energy consumption (defined as the consumption of any oil-based product) has

been steadily decreasing. In 2005 per capita energy consumption was 247 kilograms of oil. In 2007 that number was down to 225 kilograms per capita (World Bank 2010).

4.3.b. Battery Consumption

Similarly, participants reported a significant decrease in their consumption of batteries. Sixty-five percent of participants stated that they now use batteries only for their flashlights, while thirty-five percent said that they do not use any batteries since getting solar electricity. No one reported an increase in battery consumption after getting solar electricity. The reduction in battery consumption represents not only an environmental impact, but also a health impact. Rural communities in Senegal do not have garbage collection services, so used batteries typically end up littering the ground. Over time, battery acid leaks out of the used battery, posing a direct threat to those who come in contact with the dead battery, and posing a long-term threat as the acid leaches into the soil and groundwater.

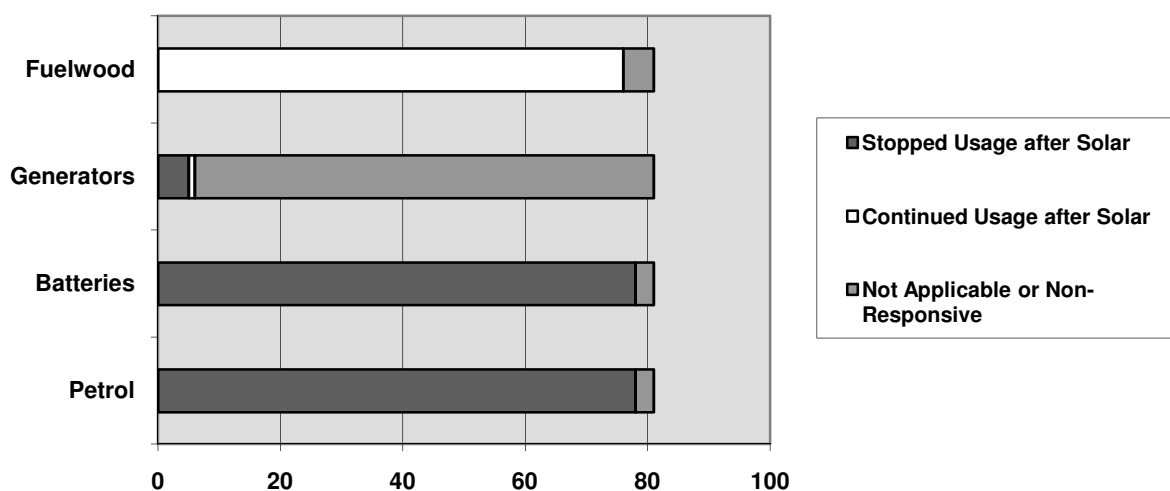
4.3.c. Diesel Fuel Consumption

Diesel-powered generators have never been common household items in Senegal, but most villages typically have one. Of those surveyed, six households reported having generators. Of those households, five indicated that they have not used their generators since getting solar electricity. One respondent said that he uses his in conjunction with solar electricity, because he has too many televisions to run solely on solar power.

4.3.d. Firewood Consumption

Cooking method was the last area of focus under the environmental impact assessment. Of those that responded, one hundred percent said that they continue to cook with fire wood since receiving solar electricity. No participants reported using electricity to cook. Thus, cooking methods have remained unchanged by the influx of solar electricity. This corresponds with data from the World Bank Group shows that the amount of forest cover in Senegal steadily decreased from 2000 to 2007 (World Bank 2010).

Figure 13. Environmental Impacts of Rural Solar Electrification



In summary, rural solar electrification has benefited the environment by reducing the consumption of petrol, batteries, and diesel fuel for generators. It has not, however, resulted in a reduction in the amount of fire wood consumed.

4.4 Social Impacts of Rural Solar Electrification

There are many possible ways of measuring the social impacts of rural solar electrification. This project measures three specific sub-sectors: women's empowerment, health, and education.

4.4.a. Education

As discussed in chapter three, rural solar electrification has many education-related applications. This study focused on four primary questions:

- Does your village have a school?
- If yes, is the village school equipped with solar electricity?
- Do your children use solar electricity to do their homework?
- How does solar electricity affect your children's education?

Seven of the ten villages surveyed have schools. The remaining three villages send their children to nearby schools. As rural Senegalese households typically contain multiple generations, the responses of elderly participants typically were in reference to grandchildren.

Of the seven communities with schools, one reported having solar electricity at their school. This solar electricity is primarily used for lighting. The participants from this community did not describe how monthly payments for the school's solar system are organized.

When asked if children use solar electricity to do homework, ninety-nine percent of participants responded affirmatively. The only participant who said his children do not use solar electricity to do homework qualified his response by saying his children do not attend school and thus have no homework. Many participants indicated that solar electricity motivates children to study at night. They explained that the electric light does not strain the children's eyes and make them sick from fumes like petrol lanterns do.

Of those surveyed, one hundred percent indicated that solar electricity positively affects children's education. "Solar helps the children learn. They use the light to do homework and the TV to get information on health education to protect themselves," said one participant. Although not a survey question, twenty-four percent of participants added that solar electricity keeps children home at night. Prior to receiving solar electricity, children would wander around the village at night, or go to the neighbor's houses to watch battery-powered television. A quarter of all participants indicated that their children are safer and their families get more time together because of this shift in behavior. One male participant said, "I get to spend time with my kids at night a lot more than I used to." A female participant said "They are safer now. I am very happy about it."

There is a clear connection between education and rural solar electrification. Solar electricity has increased children's motivation for studying at night. Solar electricity has made conditions for studying at night healthier and more comfortable. It has also led to the indirect benefit of keeping children safer and giving families more time together.

4.4.b. Women's Empowerment

To measure the impact of rural solar electrification on women's empowerment, this study focused on changes in women's ability to generate income, changes in the amount of time spent on household chores, and changes in women's literacy opportunities.

Theoretically, electricity provides women with expanded options for generating income. In Senegalese towns where women have access to centralized electricity, it is common to see women running small businesses directly from their homes. For example, a woman might offer tailor services if she owns a sewing machine. With a small refrigerator or freezer, a woman might sell cold drinks or ice. To determine if women in the surveyed villages have begun any such activities, all participants were asked if any women in their village have used electricity to generate income. Interestingly, only half of the participants answered this question. Women were more likely to answer the question than men, who seemed a bit confused by the question. None of the participants said that women have used electricity to generate income. "The women are not able to make any profit off of it, but if they could have enough (solar) panels to run a millet-grinding machine, then they could make money and they would really appreciate it," said one male participant.

Women in rural Senegal spend long hours doing household chores manually. The most time consuming tasks are collecting fire wood, pulling and carrying water from wells, and de-husking and grinding millet from breakfast and dinner. It seems that electricity

has the potential to drastically reduce the hours and energy women expend on household chores. Three machines alone—electrical cooking devices, millet grinding machines, and electrical water pumps—would possibly cut in half the amount of time women spend on household chores each day.

Section 4.3.d. described how participants were asked about cooking methods in the context of environmental impacts. The data collected in that question also has implications for women's empowerment. It highlights yet another area in which solar electricity has the potential to deliver significant improvements in women's lives, but in which that potential is not being achieved.

Another question relating to women's empowerment was: *Does your community have an electric millet grinding machine. If so, does the machine run on solar power?* Two out of ten villages reported having an electric millet grinding machine, both of which were powered by a diesel generator.

The final question in the survey relating to women's empowerment was whether or not the community had begun a literacy class since getting solar electricity. Community literacy classes are typically organized after dark, when women are more likely to be finished with daily household chores. This is only possible, however, if there is electricity for lighting. Of the villages surveyed, two had a literacy program. One of these communities has had a literacy program much longer than it has had solar electricity. The second community, Keur Mama Lamine, started a literacy program in

response to receiving solar electricity in their school. It makes sense that the only village to have a solar-powered school would be the only community to have a new literacy program. Although six other communities have schools, none of them are solar-equipped and therefore are unable to hold evening classes.

In summary, solar electricity has brought very little empowerment to rural Senegalese women, despite its immense potential for doing so. This is attributed primarily to the weakness of the solar home systems. Based on participant's comments, the solar home systems cannot sufficiently power any high-voltage appliances, such as those required to run a small business from home. Women are unable to use solar electricity to increase their income or significantly reduce their time spent on household chores. Many participants of both genders expressed interest in women being able to use the solar systems to generate income. Thus, attitudes towards income generation are positive and not a secondary barrier. The cost of purchasing small appliances could potentially be a secondary barrier, but until there is greater electrical capacity, this remains to be seen.

4.4.c. Community Health

Of the ten villages surveyed, three have community health centers. Two of the three health centers are equipped with solar electricity. The village of Daga Diawdine received a grant in the year 2000 to construct its community health center and equip it with solar electricity. Household solar home systems were installed in Daga Diawdine between 2004-2005. Thus, for a long time the community health center was the only source of

solar electricity in the village. The solar system attached to the health center has only been used for lighting. There is no refrigerator or other equipment in the health center to assist with health care. The village of Keur Mama Lamine also has a solar-powered community health center. Like the one in Daga Diawdine, the health center in Keur Mama Lamine uses its solar electricity only for lighting.

To determine if solar electricity has improved access to health education, participants were asked if they received health education from watching television. Of those that responded, every person said that they had learned about health issues from the television. Several participants referred to news programs and documentaries.

Overwhelmingly, rural populations are gaining knowledge about public health issues through television. The value of this hinges upon the quality of television programming and on people's willingness to adapt behaviors based on new knowledge. Knowledge alone does little good if behavior is not modified correspondingly.

It is promising that two out of three rural health centers are using solar electricity. If this electricity is being applied primarily for lighting, it would be interesting to learn how that lighting is being used. While it may be disappointing that none of the health centers have more creative applications of solar electricity, such as refrigeration of vaccinations or digital baby-weighing scales, such applications may require a higher level of medical training and may not be feasible with current resources.

4.5. Consumer Satisfaction with Rural Solar Electrification

Despite the limitations of solar electricity, survey participants almost unanimously indicated that they are satisfied with their solar home systems. Ninety-seven percent of participants voiced satisfaction, while only three percent voiced dissatisfaction.

Although participants are satisfied with rural solar electrification, responses were typically qualified with the phrase “yes, I like it but...” Twenty-eight percent of participants reported that solar electrification is good but too expensive. Twenty-seven percent of participants reported that solar electrification is good but far too weak.

While discussing satisfaction, participants cited the following reasons why they are happy with solar electricity:

- It cannot be put out by the wind like candles and lamps
- It does not produce a flame, so there is reduced risk of fire
- It does not make any smoke, so it is healthier
- It scares away hyenas, bugs and scorpions
- It's light is brighter, so it does not hurt eyes as much
- There is no fear of darkness with solar
- It just takes one second to light the whole house
- It motivates kids to do their homework
- It keeps families together

The quotes in Figure 4.9 highlight how some survey participants summarize their impression of rural solar electrification.

Figure 14. Direct Quotes Regarding Overall Satisfaction with Solar Electricity

<p>“It’s good because it’s better than the petrol, but it’s more expensive too. But it’s more civilized and peaceful.”</p>	<p>“It's really good because it keeps my family together. The brightness brings excitement. We all hang out, drink, tea and chat until it's time to go to sleep.”</p>
<p>“Yes, I am happy about the solar because we can watch the news and use it for our radios. But I wish it was more powerful, and that it could generate more electricity so that we could use it for things that are more productive. If it was more powerful we could use it to make a small business and make some more money off if it. But it is good because we are not buying petrol any more.”</p>	<p>“I think it is good because it got us out of darkness. It also woke us up because we learned a lot from watching the TV and the news. But I wish it was more powerful so that we could use additional appliances. And it is also expensive too. So if we cannot have it for free, I wish it was more affordable.”</p>

4.7 Limitations and Delimitations of the Study and Conclusions

As stated in chapter one, the scope of this study is small. As the data has been sorted and the impacts assessed, the limits of this study have become increasingly apparent. A few changes in survey design and research methods are recommended *post-facto*.

4.6.a. Suggestions for Survey Design

In the survey, participants and research assistants found some of the questions confusing. Although the surveyed was designed to be culturally appropriate, two questions in particular were repeat offenders: *Do women gain money from solar electricity?* and *How*

many people gain money from solar electricity? Magnifying this confusion is the fact that the Senegalese culture in general does not openly speak about their income. One way this situation may have been avoided was if the research assistants did a few test interviews prior to beginning the formal interview process. This would have allowed for any confusion to be addressed prior to the start of the data collection.

Another challenge with the survey design was that it included several multi-part questions. In the case of multi-part questions, participants typically answered only the first question. A good example of this is survey question twelve: *Do you have any problems with the solar electricity? If yes, what type of problems?* A typical response to this question was “Yes”, hence so many unspecified maintenance issues in section 4.1.c.

A significant oversight in the survey design was to not ask participants how many solar panels they have on their homes. It was assumed during the research design that solar home systems were equal in size. And quite possibly, there may be a standard size for solar home systems. However, a few participants mentioned that collectors would occasionally take away one solar panel from a household, implying that the household was being left with a smaller and less powerful system.

4.6. b. Suggestions for Research Model

As with the survey design, the research model would benefit from a few minor tweaks. For starters, the quality of the data may have been more comprehensive if the interviews had been conducted directly by the researcher rather than by research assistants. During the interviews, many participants said very interesting comments relevant to the research project. Rather than prompting the participant for more details, the research assistants moved onto the next survey question. Because the research assistants were only trained to collect the data included in the survey, there was a missed opportunity for additional, qualitative data.

Procedurally, it was inefficient to compile all recorded interviews, ship them as a group to the United States, and then translate and transcribe them consecutively. A more effective method would have been to ship all interviews as soon as they were recorded, grouped perhaps by village. This would have allowed any challenges with the survey design to be addressed while the interviews were still in progress, rather than after all interviews were completed. Additionally, an immense amount of time was required to translate the interviews. Shipping the interviews in smaller groups as soon as each village was complete would have allowed the translation process to begin much earlier.

A final challenge with the research method was the lack of balance between male and female participants. Research assistants were instructed to interview a balanced number of males and females, but they were not able to achieve this goal. Rural households in Senegal are run by men, and it is culturally expected that questions about solar electricity

will be directed to men. One way around this would have been to require that the research assistants interview one man and one woman from each household.

4.6.c. Conclusions

Based on the data collected in this study, it is clear that rural solar electrification is impacting rural populations in a variety of ways. The most significant impacts seem to be in the areas of education and the environment. The health sector is being impacted as well, but to a lesser extent. Rural solar electrification seems to have at least impact on economic growth and women's empowerment. The data also points to areas of concern in the administration of rural solar electrification. Highest among these concerns are the overall weakness of the solar home systems, the tendency of solar home systems to breakdown, the high cost burden these systems place on rural farmers, and the unpredictable fee collection pattern. The following chapter explores recommendations for improving the administration and impact of rural solar electrification in Senegal.

CHAPTER FIVE RECOMMENDATIONS

The electrification of rural Senegal is bringing changes big and small to residents of the Fatick region. While communities with solar electricity are not yet seeing significant improvement in their economic situation or with women's empowerment, they are experiencing advancements in education and community health while experiencing reductions in fossil fuel consumption. To maximize the impact of rural solar electrification programs in Senegal, the below chart outlines an action plan, divided into recommendations for the Government of Senegal, the international public sector, the private sector, and Senegal's civic sector.

Table 6. Recommendations for improving the impact of RSE programs in Senegal

	Recommendations for the Government of Senegal
1	Coordinate international stakeholders and align goals into an organized approach to rural solar electrification
2	Set feasible limits on expected household contributions for decentralized electricity
3	Transition from a flat rate fee structure to a pay-for-usage fee structure
4	Create a standardized and transparent payment system
5	Clarify ownership of solar home systems
6	Conduct regularly scheduled evaluations of rural solar electrification projects
7	Design and implement a pre-installation orientation for communities receiving solar systems
	Recommendations for the International Public Sector
8	Carefully assess the appropriateness of green technology transfers under the CDM

	Recommendations for the Private Sector
9	Continue to research and develop new solar technologies
10	Dedicate an increased amount of financing to solar initiatives in partnerships with the public and civic sectors
11	Approach rural electrification programs in developing countries through framework of Corporate Social Responsibility
	Recommendations for Senegal's Civic Sector
12	Lead community organization initiative to promote public uses of solar electricity
13	Develop culturally-appropriate methods for cooking traditional Senegalese food with solar electricity
14	Ensure accountability by auditing confiscated solar equipment

5.1 Recommendations for the Government of Senegal

As noted in chapter one, stakeholders from the three sectors are involved in the rural electrification of Senegal. Each group has their own agenda and priorities, and the result has been a chaotic process of rural solar electrification. The first priority of the Senegalese government moving forward should be to **coordinate international stakeholders into an organized approach to rural solar electrification**. The village-to-village disparities in program administration and cost indicate that there is no effective large-scale coordination effort currently underway. The Government of Senegal has the infrastructure in place to implement this, under the direction of its Agency for Rural Electrification (ASER). ASER's inability to share a comprehensive list of electrified communities in the Fatick region illustrates the agency's current lack of knowledge of on-going activities and programs. ASER can and should serve as a portal for all rural solar electrification projects. This would give the Government of Senegal an increased

ability to oversee and coordinate rural electrification projects, with the intention of eliminating disparities between villages and sharing best practices between stakeholders.

In addition to requiring that all partners work through ASER, the Government of Senegal should **re-evaluate and prioritize goals for rural solar electrification**. The government must decide whether the goal of these programs is to deliver electricity to rural populations or to support and expand the green technology market. It would be ideal if these two goals were complementary. But as illustrated in the literature review, that is not always the case. Contreras demonstrated that diesel-solar hybrid systems are often more economical than solar systems. Wamukonya calculated that decentralized electricity is two to four times more expensive than centralized electricity. “Synergies do not naturally emerge just because rural poverty reduction and natural resource conservation are each appealing goals with common drivers and some intrinsic interlinkages” (Barrett et al. 2005). While it may be true that international partners are more interested in funding green technology, it is the responsibility of the Government of Senegal to ensure that its country and its citizens do not get the short end of the straw. Rural Senegalese, who are among the world’s more impoverished populations, do not have the luxury of paying higher prices for electricity just because it is green.

Another recommendation for the Government of Senegal is to **set feasible limits on expected household contributions for decentralized electricity**. This limit should be based on an analysis of household ability-to-pay, rather than on what the government requires to pay off equipment-related debt. The participants of this study spend an

estimated twelve to thirty-six percent of their annual income on electricity. This is an unsustainable percentage. It is unlikely that rural residents would be able to sustain such high payments over the long run. To make up for the difference between household ability-to-pay and the required pay off amounts, the Government of Senegal may extend the terms of its financing, or it may request increased subsidization from its international partners.

In addition to setting a payment cap, the Government could **transition from a flat rate fee structure to a pay-for-usage fee structure**. This could be accomplished by installing meters and charging a fixed rate per kilowatt hour. During difficult financial times, households could opt to scale back on electrical consumption in order to reduce their monthly fees without the risk that their solar home system would be removed. One possible barrier to this suggestion is that illiterate households may not understand how to read the meter. Alternatively, households could pay a flat fee per solar panel and choose how many panels they can afford. Having fewer panels would limit a household's ability to generate, store, and use electricity, without completely eliminating their access to solar electricity.

In addition to aligning fees with the ability of households to pay, the Government of Senegal needs to **create a standardized and transparent accounting system** for solar consumers. Table 4.1 *Reported Solar Fee Schedule* illustrates the lack of consistency in payment collection. Figure 4.3 *Direct Quotes on Solar Fee Schedule* showcases the frustrations rural residents feel regarding the current collection system. While the current

system may have been designed to offer maximum flexibility to rural consumers, feedback indicates that the current system is too flexible and lacks transparency. The government needs a new collection system that retains flexible monthly payments, but with a clear collection framework so that rural residents understand the expectations placed on them. Rather than traveling from household to household within participating villages, the government could set up collection centers at weekly markets. Because weekly markets draw residents from multiple neighboring villages, this would reduce the amount of time needed to collect fees. This time could be invested instead in maintaining a record of payments received. Residents need access to a written payment record. Currently, residents are unsure if collectors are reporting their full payments. This lack of record keeping limits the transparency of the collection system. In a separate but related issue, the Government should **clarify ownership of solar home systems**. Residents are unsure if their payments represent payment for possession of the solar home systems, or rental of solar home systems. Having a sense of ownership may motivate residents to make their payments and properly maintain their solar home systems.

Under the purview of ASER, the Senegalese government should also **conduct regularly scheduled evaluations of rural solar electrification projects**. Such evaluations would allow the government to analyze the strengths and weakness of any rural electrification program. It would allow best practices to be highlighted and potentially shared. It would afford the government a better overall understanding of how rural solar electrification impacts the lives of its citizens.

Finally, the Government of Senegal should **design and implement a pre-installation orientation for communities receiving solar systems**. This would eliminate much of the current confusion over program administration and fees. An orientation could clarify system limitations, and offer hands-on lessons in system maintenance and basic repairs.

5.2 Recommendations for the International Public Sector

As discussed briefly in chapter two, countries or private companies who transfer green technologies to developing nations qualify for carbon credits under the Clean Development Mechanism of the Kyoto Protocol. The CDM is administered by the international public sector and the United Nations. It is imperative that the UN **carefully assess the appropriateness of green technology transfers under the CDM**.

When a private company receives permission to pollute more in exchange for disseminating solar technology to people who consume miniscule amounts of energy and produce insignificant amounts of Carbon Dioxide, one might reasonably question the net environmental benefit of such a transaction. Perhaps the assumption is that such green technology transfers will facilitate the development process, and over time negate any potential increases in energy consumption. But considering that rural Senegalese are paying twelve to thirty-six percent of their annual income for electricity so weak that it can only run a few light bulbs and one black and white television, that assumption becomes improbable, and the whole process looks a bit more like green washing than leapfrogging.

5.3 Recommendations for the Private Sector

It is the creativity and innovation of the private sector that has made much of today's solar technology available. As with any emerging technology, solar technology will continue to improve and the cost will continue to decline. One significant impact the private sector could have on rural solar electrification would be to **continue to research and develop new solar technologies**, particularly ones with increased capabilities for generating and storing electricity at a decreased cost. As voiced by numerous survey participants, the solar home systems currently in use are not strong enough to support full household demand, let alone income generating activities. With increased capabilities to generate income, rural residents would have an increased capability to pay for solar electricity, and this in time would serve to effectively expand markets for solar technologies.

To encourage this expansion of solar markets, the private sector should **dedicate an increased amount of financing to rural solar electrification projects**. Microfinance models could be adapted to help communities cover the high upfront costs, for both domestic and public uses of solar electricity. Sector-specific associations, such as the Alliance for Rural Electrification (<http://www.ruralelec.org/>), provide an opportunity for increased coordination of private businesses.

Finally, the private sector should **approach rural electrification programs in developing countries through a framework of Corporate Social Responsibility**

(CSR). Electricity should be viewed as “a social amenity that can help lift the poor out of poverty” (Gaye 2007), rather than simply as a source of profit. Although outside the purview of this thesis, CSR has become increasingly popular among today’s global companies. “Business has the capacities that other social actors lack: it has global reach, through transnational firms and supply chains; it directly affects communities in which it operates; and it can move at speeds that few governments or international agencies are able to match” (Fussler, Cramer and van der Vegt 2004, 15). Clearly, the private sector is an important stakeholder in rural solar electrification programs.

5.4 Recommendations for Senegal’s Civic Sector

Senegal’s strong civic sector is well-positioned to address some areas of need in regards to rural solar electrification. Specifically, Senegal’s third sector could work to **expand the utilization of solar electricity from domestic uses to public uses**. According to the results of this survey, solar electricity is being used primarily for domestic uses such as lighting, televisions and radios. Beyond such domestic uses, solar electricity is being used publically in one school and two health centers. The village of Daga Babou also reported using solar electricity in its church and mosque. Community-based organizations throughout Senegal could assist communities in conducting needs assessments, helping them to prioritize public uses for electricity. Such community organizing could have the added benefit of coordinating funding of publicly consumed electricity.

A second area in which the civic sector could be of great use relates to the overuse of fuel wood for cooking. There is a need in rural areas to **develop culturally-appropriate methods for cooking traditional Senegalese food with solar electricity**. The complimentary threats of deforestation and desertification in the Fatick region of Senegal ensure that rural residents will not be able to continue cooking with fuel wood much longer. This one development, if done well, would magnify the environmental impacts of rural solar electricity.

Senegal's civic sector could further impact rural solar electrification by working to **ensure accountability by auditing confiscated solar equipment**. Confiscated equipment refers to solar equipment that fee collectors remove from homes when residents do not pay. As mentioned in Chapter Four, it is unclear to residents what factors result in the removal of solar equipment. Some families have solar equipment removed after one missed payment, while other families are permitted to miss several consecutive payments before their equipment is removed. It is unclear what happens to the solar equipment once it is removed. One participant voiced suspicions that fee collectors were removing solar equipment from villages, reporting the equipment as stolen to the government, and then selling the solar equipment on the black market for a high profit. This suspicion is collaborated by a 2005 study, which indicated that solar equipment is stolen by the same technicians who install them (Faye 2006). The same report indicated that approximately fifteen per cent of solar equipment has been reported as stolen to authorities. It is noted that none of the survey participants reported equipment theft during their interviews.

5.6 Conclusions

Promising, but poorly managed. This is the best way to summarize Senegal's current rural solar electrification efforts. Solar electricity in rural areas is relatively new and residents are generally excited about it. Overwhelmingly, though, they also feel confused as to their financial obligations and are disappointed by the high costs and system limitations. It is unsustainable to expect some of the world's poorest people to spend twelve to thirty-six percent of their income on low quality electrical service, especially when that low quality electrical service is too weak to be used for income generation. Once the novelty of solar electricity wears off, Senegal may see a decline in the number of households willing to pay for solar home systems. To prevent this from happening, the Senegalese government must work to get the cost down and the quality of service up.

This study indicates that rural solar electrification, even at its weakest form, leads to measurable changes in education, health, and fossil fuel conservation. This study further indicates that rural solar electrification programs in the Fatick region of Senegal have results in no positive impacts on economic development or women's empowerment.

Rural solar electrification has the potential to bring countries closer to achieving their Millennium Development Goals. However, without better planning, implementation and management, rural solar electrification programs will fail to achieve their potential, and may end up looking more like green washing than green development. "Technology leapfrogging can exist, but leapfrogging alone does not guarantee, or even encourage,

prosperity. This depends on the policy environment, how leapfrogging is operationalised, who is involved and who undertakes to support initiatives” (Davison et al 2000).

The take home lesson of this thesis is not that rural solar electrification programs insufficiently bring about international development. Rather, the take home lesson is: rural solar electrification programs are capable of more than just a green façade. If we as an international community are going to do this, let’s do it right. Let’s coordinate, communicate, monitor and evaluate. Let’s learn lessons and build a broader dialogue amongst stakeholders. Let’s focus not on the audacity of solar panels on mud huts, but rather on how big of a splash we can make as we collectively leap into the new energy economy.

APPENDIX A

SURVEY QUESTIONS IN ENGLISH

General Questions
1.) Where do you live?
2.) How old are you?
3.) How many people live in your village?
4.) How many people live in your home?
5.) How do you support your family?
6.) Do you have solar electricity in your home?
7.) What type of solar system do you have?
8.) How do you use your solar electricity?
9.) How much does it cost you?
10.) How frequently do you pay for your solar electricity?
11.) Have you had any problems with your solar electricity? If so, what type of problems?
12.) Who is in charge of maintaining your solar equipment?
13.) Are you happy with your solar electricity?
14.) Does your village have a school, a health center, or a millet grinding machine? If so, do they use solar electricity? How?
Economic Indicators
15.) Have you gained or lost money from the solar electricity? If yes or no, please explain.
16.) Has solar electricity helped you save any money?
17.) Since getting solar electricity, have you built a new home or purchased any property (ie: car, boat)?

Social Indicators
<p>18.) Has solar electricity affected the education of your children? If yes, how?</p> <p>19.) Do your children use solar electricity to do their homework?</p> <p>20.) Have you learned health news from the TV?</p> <p>21.) Are women in your village able to generate income from solar electricity?</p> <p>22.) Since getting solar electricity, has your village started a literacy class?</p> <p>23.) Does solar electricity save you time?</p>
Environmental Indicators
<p>24.) Since getting solar electricity, do you use more or less petrol? Why?</p> <p>25.) Since getting solar electricity, do you use more or less batteries? Why?</p> <p>26.) Since getting solar electricity, have you bought any electronics? If so, what?</p> <p>27.) Does your family own a generator? If yes, how do you use it?</p> <p>28.) Does your family cook with wood or electricity?</p>
Conclusion
<p>29.) What do you think of solar electricity?</p>

APPENDIX B

SURVEY QUESTIONS IN FRENCH

Information Générale
1.) Où habitez-vous ?
2.) Quel age avez-vous?
3.) Combien de personnes vivent dans votre village?
4.) Combien de personnes vivent dans votre maison?
5.) Comment soutenez-vous votre famille?
6.) Y a-t-il l'électricité solaire dans votre maison?
7.) Quel type d'électricité solaire avez-vous? (système à la maison solaire, mini-grille solaire, système diesel solaire hybride, grille solaire centralisée)
8.) Comment utilisez-vous l'électricité solaire?
9.) Combien ça vous coûte?
10.) Payez-vous par mois, par semaine?
11.) Avez-vous des problèmes avec votre électricité solaire? Si oui, quelle genre de problèmes?
12.) Qui est en charge du maintienance de l'équipement solaire?
13.) Etes-vous heureux avec l'électricité solaire?
14.) Avez-vous un école ou un cas de santé ou un Moulin? Est-ce qu'ils utilisent de l'électricité solaire? Comment?
Indicateurs Économiques
15.) Gagnez-vous de l'argent ou perdez-vous de l'argent à cause de cette électricité solaire? Si oui ou non, expliquez.
16.) Épargnez-vous de l'argent à cause de cette électricité solaire?
17.) Depuis que vous possédez cette électricité solaire, avez-vous construit une nouvelle maison, ou achetez une voiture, ou une pirogue?

Indicateurs Sociaux
<p>18.) L'électricité solaire a affecté l'éducation de vos enfants ? Si oui, comment?</p> <p>19.) Est-ce que vos enfants utilisent l'électricité solaire pour faire les devoirs?</p> <p>20.) Avez-vous appris nouveau a propos de votre sante a la television?</p> <p>21.) Est-ce que les femmes gangner plus d'argent a cause d l'électricité solaire?</p> <p>22.) Depuis que vous obtenez l'électricité solaire, est-ce que votre communauté a commencé des programmes d'alphabetization?</p> <p>23.) Est-ce que l'électricité solaire vous gagne de temps?</p>
Indicateurs Environnementaux
<p>24.) Depuis que vous avez de l'électricité solaire, utilisez-vous néanmoins de petrol? Si oui, pourquoi faire?</p> <p>25.) Depuis que vous avez de l'électricité solaire, utilisez-vous néanmoins de batteries? Si oui, pourquoi faire?</p> <p>26.) Avez-vous acheté de nouvelles appareils électroniques depuis que vous avez l'électricité solaire?</p> <p>27.) Votre famille a un group (generator)? Si oui, pourquoi faire?</p> <p>28.) Faites-vous la cuisine avec du bois ou en electricite?</p>
Conclusion
<p>29.) Qu pensez-vous en generale de l'électricité solaire?</p>

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